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THE COMMERCIAL SPACE LANDSCAPE: INNOVATION, MARKET, AND POLICY

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE AND AERONAUTICS

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED SIXTEENTH CONGRESS

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July 25, 2019

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THE COMMERCIAL SPACE LANDSCAPE: INNOVATION, MARKET, AND POLICY

THURSDAY, JULY 25, 2019

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON SPACE AND AERONAUTICS,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to notice, at 2:11 p.m., in room 2318 of the Rayburn House Office Building, Hon. Kendra Horn [Chairwoman of the Subcommittee] presiding.

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

HEARING CHARTER

"The Commercial Space Landscape: Innovation, Market, and Policy"

Thursday, July 25, 2019
2:00 p.m.
2318 Rayburn House Office Building

PURPOSE

The purpose of the hearing is to provide an overview of the commercial space industry, including innovative capabilities, the market, policy issues, and associated matters.

WITNESSES

- **Dr. Bhavya Lal,** Research Staff Member, IDA Science and Technology Policy Institute
- **Ms. Carissa Christensen,** Chief Executive Officer, Bryce Space and Technology
- **Mr. Eric Stallmer,** President, Commercial Spaceflight Federation
- **Mr. Michael French**, Vice President, Space Systems, Aerospace Industries Association
- **Ms. Laura Montgomery,** Proprietor, Ground Based Space Matters and Professor, Catholic University's Columbus School of Law

OVERARCHING QUESTIONS

- *What types of innovate capabilities are influencing, or may influence, the growth of commercial space?*
- *What is the overall size of the commercial space market, and how is the industry structured?*
- *How can the government consider engaging in commercial capabilities in space?*
- *What are the key issues facing the commercial space industry?*

BACKGROUND

Space Economy

The Space Foundation, a nonprofit space organization, releases a now quarterly report on global space activity, including trends in the space economy, infrastructure, products, services, and the workforce. The global space economy is the sum of world government spending on space and commercial companies' revenues, excluding government contracts. Commercial revenues include the sale of products and services enabled by space assets and the products and services that enable private entities to access and use space. The Space Foundation's 2019 Quarter 2

report estimates that global space economic activity grew 8.1 percent from 2017 to 2018 to a total of $415 billion, of which $329 billion (79 percent) is commercial revenue.[1]

The Space Foundation's report on the global space economy, *The Space Report 2018,* analyzed the year 2017 and is the most recent Space Foundation assessment of the commercial space sector.[2] The report found that in 2017, total global commercial space activity was $307 billion. The largest areas of activity were:

- Direct-to-home television: $98 billion (32 percent of commercial activity)
- Position, navigation, and timing: $82 billion (27 percent)[3]
- Satellite communications: $23 billion (8 percent)
- Commercial satellite manufacturing: $7 billion (2 percent)
- Satellite radio: $5 billion (2 percent)
- Earth observation: $3 billion (1 percent)
- Commercial launch industry: $2 billion (1 percent)

The public and private demand for satellite services from commercial and government customers supports sizeable, growing markets in satellite manufacturing and launch services. The Satellite Industry Association's *2019 State of the Satellite Industry* report finds commercial revenues from the manufacture of commercial and government satellites totaled nearly $20 billion in 2018 alone, up 26 percent from the year prior.[4] The same report finds even larger growth in launch industry revenues from commercial and commercially-procured government launches, up 34 percent to $6.2 billion in 2018. In 2018, two of the three largest manufacturers of commercial satellites were American companies, according to the Space Foundation's 2019 Quarter 1 report.[5]

Many recent industry analyses assert that the space economy will grow significantly over the next two decades to reach at least $1 trillion by approximately 2040.[6][7][8][9] However, some space

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[1] Space Foundation, *The Space Report 2019 Q2*, July 15, 2019.
[2] Space Foundation, *The Space Report 2018*, July 19, 2018.
[3] Position, navigation, and timing revenues stem almost entirely from the commercial use of government satellites, such as the U.S. Air Force's Global Positioning System (GPS).
[4] Satellite Industry Association, *2019 State of the Satellite Industry Report*, May 2019, prepared by Bryce Space and Technology. Available at: https://www.sia.org/wp-content/uploads/2019/05/2019-SSIR-2-Page-20190507.pdf
[5] Space Foundation, *The Space Report 2019 Q1*, April 11, 2019.
[6] Swiss bank UBS predicts the global space economy will reach $926 billion annually by 2040. See: UBS Editorial Team, "Still over the moon, 50 years later," UBS, July 18, 2019. Available at: https://www.ubs.com/global/en/wealth-management/marketnews/home/article.1441593.html.
[7] Goldman Sachs predicts the global space economy will hit $1 trillion in the 2040s and Bank of America Merrill Lynch estimates the space economy will reach as high as $2.7 trillion in the 2040s. As reported in: Foust, Jeff, "A trillion-dollar space industry will require new markets," *SpaceNews*, July 5, 2018. Available at: https://spacenews.com/a-trillion-dollar-space-industry-will-require-new-markets/
[8] Morgan Stanley expects space revenues, a subset of the space economy, to be slightly more than $1 trillion by 2040. See: Morgan Stanley, "Space: Investing in the Final Frontier," July 2, 2019. Available at: https://www.morganstanley.com/ideas/investing-in-space
[9] The U.S. Chamber of Commerce predicts a space economy of $1.5 trillion by 2040. See: Higginbotham, Brian, "The Space Economy: An Industry Takes Off," U.S. Chamber of Commerce, July 11, 2018. Available at: https://www.uschamber.com/series/above-the-fold/the-space-economy-industry-takes.

industry professionals have cautioned that even the lowest market analyses may be overly optimistic.[7 10]

A venture capital firm, Space Angels, releases quarterly reports on global space investments. In the first two quarters of 2019, $2.9 billion was invested in space companies.[11] Since 2009, $22.3 billion has been invested in 476 unique companies, 54 percent of that investment has been in U.S. companies.

Workforce

The global space economy relies on a skilled workforce, including engineers and technicians. The Space Foundation's 2019 Quarter 1 report notes that the U.S. space workforce had more than 179,000 workers in 2018, which includes 135,000 in the private sector, 27,000 military personnel or national security civil servants, and 17,000 NASA civil servants.[5] The number of workers in the communications satellite manufacturing and services, guided missiles, and space vehicles sectors of the U.S. space workforce, after 8 consecutive years of decline, increased both in 2017 and the first half of 2018 over the previous year. However, workforce levels in those core sectors, were still 16 percent lower than they were in 2008. The same report found that space vehicles manufacturing (including guided missiles) and satellite telecommunications sectors saw job growths of 6.2 percent and 7.2 percent, respectively, while the broadcast and wireless communications equipment sector saw a 2.1 percent job loss.[5]

According to the 2018 *Aviation Week* Workforce Study, in 2017, women comprised 24 percent of the total U.S. aerospace and defense workforce, while minorities made up 26.7 percent of the aerospace and defense workforce.[12] The proportion of women and minorities in executive positions was significantly lower.

The 2019 Quarter 1 Space Foundation report found that Europe's space workforce has grown by an average of 4 percent annually since 2007.[5] In Japan, the space workforce declined 3.2 percent in 2018, but it has seen a strong decade of growth overall. India's workforce increased 4.6 percent in 2018, but was essentially flat compared to in 2011.

Commercial Innovations and New Capabilities

Several factors have helped enable innovative capabilities and potential new commercial space services and operations. The use of commercial off-the-shelf products, advanced information technologies, lower launch costs, and modern manufacturing process have facilitated the evolution of commercial space activities, including new capabilities and new entrants into the commercial space market.

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[10] O'Sullivan, Sinéad, "Understanding the Space Economy," interview with the *Harvard Business Review*, May 28, 2019. Available at: https://hbr.org/ideacast/2019/05/understanding-the-space-economy.html

[11] Space Angels, "Space Investment Quarterly: Q2 2019," July 11, 2019. https://www.spaceangels.com/post/q2-2019-space-investment-quarterly

[12] Aviation Week Network, "2018 Aviation Week Workforce Study Report," September 18, 2018. Available at: https://aviationweek.com/2018-aviation-week-workforce-study-report.

Historically, launch costs have been seen as one of the major barriers to entry for new space companies. In recent years, innovations in rocket design and manufacturing have lowered per-launch costs as well as increased launch cadences.[13] Lowered launch costs and a more diverse array of launch options has made it easier for new companies to enter the market.

Improvements in the manufacturing industry from automation, artificial intelligence, and increasing efficiencies are creating new business opportunities. Some satellites today are forty times lighter than traditional satellites while still providing the same services, which dramatically lowers production and launch costs.[13] Lessons from the high-volume manufacturing industry and the attendant data is being used to enable the mass production of spacecraft and launchers, lowering total production costs.[14] Improvements in the throughput of satellite communication allow companies to provide high-speed data that is 20 times faster than traditional satellites, fast enough to compete with ground-based fiber optic networks.[13]

In addition, decreases in cost and technological improvements in areas such as processing power, data storage, camera technology, solar array efficiency, and micro-propulsion have been adapted into a variety of space related areas, including telecommunications, Earth observations, and even science and exploration missions.[13]

The factors noted above have, in part, helped facilitate a host of potential new commercial space activities and services. Some commercial space companies are planning to provide services including tracking space debris for space situational awareness or on-orbit satellite servicing. Space-based suborbital and orbital tourism are also anticipated to become available.[15] Other companies are hoping to manufacture products in space that benefit from the microgravity or zero-gravity environment, such as fiber-optic cables, LEDs, crystals, metal alloys, or even human organs.[16] In addition, some industry providers that had largely served government markets have been expanding their services for non-government customers, such as the use of Earth observation imagery data for customers and users ranging from agricultural entities to fast food businesses.[17]

Current Commercial Space Policies

Signed in 1967, the Outer Space Treaty provides the framework for international space law and policy, holding nations responsible for all activities in space conducted by either their governmental or their non-governmental actors. In particular, Article VI of the Outer Space Treaty states that "*the activities of non-governmental entities in out space, including the Moon*

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[13] Lal, Bhavya, "Reshaping Space Policies to Meet Global Trends," *Issues in Science and Technology,* Summer 2016. Available at: https://issues.org/reshaping-space-policies-to-meet-global-trends/

[14] Institute for Defense Analyses Science and Technology Policy Institute, "Global Trends in Space Volume 1: Background and Overall Findings," June 2015. Available at: https://www.ida.org/-/media/feature/publications/g/gl/global-trends-in-space-volume-1-background-and-overall-findings/p5242v1.pdf

[15] REVFINE "Space Tourism: 5 Space Companies That Will Make You an Astronaut." Available at: https://www.revfine.com/space-tourism/

[16] Lewin, Sarah, "Making Stuff in Space: Off-Earth Manufacturing is Just Getting Started," *Space*, May 11, 2018. Available at: https://www.space.com/40552-space-based-manufacturing-just-getting-started.html

[17] GISGeography, "100 Earth Shattering Remote Sensing Applications and Uses," February 10, 2019. Available at: https://gisgeography.com/100-earth-remote-sensing-applications-uses/

and other celestial bodies, shall require authorization and continuing supervision by the appropriate State Party to the Treaty."[18] Congress has given statutory authorities to certain Federal agencies to meet the United States' international obligations under the Outer Space Treaty for non-governmental space activities. The Federal Aviation Administration (FAA) licenses launch, reentry, and launch and reentry sites; the Federal Communications Commission (FCC) licenses radio communications; and the National Oceanic and Atmospheric Administration (NOAA) licenses commercial remote sensing systems.

In May 2018, the administration issued Space Policy Directive-2 (SPD-2),[19] a presidential memorandum that instructs various federal agencies to streamline regulations on the commercial use of space. Below, the current state of commercial space regulations and corresponding proposed new rulemaking efforts in according with SPD-2 are briefly described.[20]

Launch, Reentry, and Spaceports: FAA

The Office of Commercial Space Transportation (AST) within the FAA issues commercial space transportation licenses and experimental permits, under authority granted to the Department of Transportation.[21] Licenses are required to launch a launch vehicle, operate a launch or reentry site (spaceport), or reenter a reentry vehicle within U.S. borders, as well as for any U.S. citizen or U.S. entity (including companies only organized within a foreign country but of which a U.S. citizen or U.S. entity holds a controlling share) to out a launch or reentry abroad. As of May 2019, the FAA has licensed or permitted more than 370 launches and reentries, and twelve commercial spaceports currently hold active licenses.[22]

Consistent with SPD-2, the FAA released a Notice of Proposed Rulemaking (NPRM) on April 15, 2019 with the intent of streamlining launch and reentry licensing requirements.[23] The public comment period for the NPRM has been extended through August 19, 2019.

Satellite Communications: FCC

Under its authority to regulate all radio communication and transmission under the Communications Act of 1934[24] and the United States' obligations under the International

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[18] "Treaty on the Principles Governing the Activities of State in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies," ratified 1967. Available at: http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/outerspacetreaty.html

[19] Space Policy Directive-2, "Streamlining Regulations on Commercial Use of Space," May 24, 2018. Available at: https://www.whitehouse.gov/presidential-actions/space-policy-directive-2-streamlining-regulations-commercial-use-space/

[20] More detail on the current state of regulations and rulemaking efforts can be found in Congressional Research Services Report R45416, *Commercial Space: Federal Regulation, Oversight, and Utilization*, by Daniel Morgan, November 29, 2018. Available at: https://crsreports.congress.gov/product/pdf/R/R45416/2

[21] Title 51, U.S. Code, Section 50904(a) Available at: https://www.law.cornell.edu/uscode/text/51/50904

[22] FAA, "Fact Sheet – Commercial Space Transportation Activities." May 29, 2019. Available at: https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=19074

[23] FAA-2019-0229. Streamlined Launch and Reentry Licensing Requirements. Available at: https://www.regulations.gov/docket?D=FAA-2019-0229

[24] Title 41, U.S. Code, Section 152(a). Available at: https://www.law.cornell.edu/uscode/text/47/152

Telecommunications Union (ITU) Radio Regulations,[25] the FCC issues licenses for private space-based communications. Satellites communicate with other satellites and with ground systems over radio frequencies, and thus must obtain FCC licenses for access to a given spectral frequency or band. Most private satellites are licensed through the Satellite Division of the FCC's International Bureau.

In May 2018, the FCC released an NPRM[26] proposing to revise licensing procedures for small satellites; the NPRM sought public comment in part on what the FCC's definition of "small satellites" should be, as different entities define them in a variety of ways. On July 11, 2019, the FCC released a new draft of the policy to be considered at its August 2019 Open Meeting.[27]

Remote Sensing from Space: NOAA

The Land Remote Sensing Policy Act of 1992 authorizes the Secretary of Commerce[28] to issue licenses for operation of commercial remote sensing systems on space-based platforms. As defined in the Code of Federal Regulations, a "remote sensing space system" is one capable of "*actively or passively sensing the Earth's surface, including bodies of water, from space by making use of the electromagnetic waves emitted, reflected, or diffracted by the sensed objects.*"[29] The Department of Commerce oversees the issuance of commercial remote sensing licenses through the Commercial Remote Sensing Regulatory Affairs Office (CRSRA) within NOAA. Similar to the other licenses for commercial space activities, NOAA licenses are required for any U.S. citizen, U.S. entity, or foreign entity with substantial U.S. connection.

In June 2018, NOAA issued an Advance Notice of Proposed Rulemaking[30] with a draft revision of the current regulations governing commercial remote sensing licensing. NOAA issued an updated Proposed Rule[31] in May 2019, for which the public comment period recently ended. The stated intention of the NPRM is to reflect changes in the industry and improve the regulatory approach, in accordance with SPD-2.

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[25] The ITU Radio Regulations were first adopted in 1995, and last revised at the 2015 World Radiocommunication Conference (WRC-15). The next WRC will take place in October 2019. More information: https://www.itu.int/pub/R-REG-RR/en

[26] FCC, "Streamlining Licensing Procedures for Small Satellites," 83 *Federal Register* 24064, May 24, 2018. Available at: https://www.federalregister.gov/documents/2018/05/24/2018-10943/streamlining-licensing-procedures-for-small-satellites

[27] FCC, "Streamlining Licensing Procedures for Small Satellites," Public Draft, July 11, 2019. Available at: https://www.fcc.gov/document/streamlining-licensing-procedures-small-satellites-0

[28] Title 51, U.S. Code, Section 60121. Available at: https://www.law.cornell.edu/uscode/text/51/60121

[29] Title 15, U.S. Code of Federal Regulations, Part 960.3. Available at: https://www.ecfr.gov/cgi-bin/text-idx?SID=95e2df51e3d82db5c6c2d7c7fd4df4f6&mc=true&node=se15.3.960_13&rgn=div8

[30] Department of Commerce, NOAA, "Licensing Private Remote Sensing Systems," 83 *Federal Register* 30592, June 28, 2018. Available at: https://www.federalregister.gov/documents/2018/06/29/2018-14038/licensing-private-remote-sensing-space-systems

[31] Department of Commerce, NOAA, "Licensing of Private Remote Sensing Systems," 84 *Federal Register* 21282, May 14, 2019. Available at: https://www.federalregister.gov/documents/2019/05/14/2019-09320/licensing-of-private-remote-sensing-space-systems

Other Policies for Commercial Space

Licenses to export some commercial space technologies are issued by the Department of State, if they are subject to the International Traffic in Arms Regulations (ITAR).[32] Other export control licenses are issued by the Department of Commerce for technologies which are subject to the Commerce Control List.[33]

The Department of State's Office of Space and Advanced Technology leads U.S. government consultations with other countries and international organizations on space policy and law.

[32] https://www.pmddtc.state.gov/ddtc_public?id=ddtc_kb_article_page&sys_id=%2024d528fddbfc930044f9ff621f961987

[33] https://www.bis.doc.gov/index.php/regulations/commerce-control-list-ccl

Chairwoman HORN. This hearing will come to order. Without objection, the Chair is authorized to declare a recess at any time. Good afternoon, everyone, and welcome to today's hearing on "The Commercial Space Landscape: Innovation, Market, and Policy". I especially want to thank our distinguished panel of witnesses today, and express my gratitude for you being here.

From the Apollo program, and the 50th anniversary of Apollo 11 that we just celebrated, to the Viking landers on Mars, the Landsat Earth observing satellites, and the Hubble Space Telescope, the private space sector has been a trusted partner in America's civil space program. While Federal Government has taken the lead in R&D (research and development) investments, design, development, testing, and construction of infrastructure and facilities, it has looked to the aerospace industry, and its skilled workforce, to implement the government's mission requirements, and build many of the spacecraft, instruments, vehicles, satellites, and systems that the government has launched into space. This partnership has worked well, and the Nation's successes in civil space owe much to the partnership between government and industry.

Through these government investments, demonstrated capabilities have led to flourishing segments of the commercial space industry, and today the global space economy, including government space budgets, is estimated to be around $350 to $400 billion. Sectors within that global economy, such as satellite television, satellite manufacturing, and ground equipment and devices, like the chips in our smartphone that enable navigation, produce annual revenues in the tens to hundreds of billions of dollars. Congress and government policies as well have supported the development of a commercial space industry by setting the frameworks for regulating segments of the industry. This Committee's *Commercial Space Launch Act of 1984* laid the initial regulatory framework to enable the emergence of a commercial space launch industry, for example. Other legislation provided a pathway for commercial remote sensing licensing, and today the commercial space industry is evolving.

With these changes have come innovative technologies and operations, and potential new services and capabilities that are infusing energy and excitement into the commercial space industry. Private investors, venture capital, and other forms of investment are also expressing interest, and investing in the industry. According to one source, total investment in startup space companies was at a record $3.2 billion in 2018, up from about $2.5 billion in 2017. We are on the precipice of what could be a groundbreaking shift in technologies and services that affect our daily lives, whether through new broadband communication services, or information products derived from Earth remote sensing imagery. I'm excited about the future of commercial space, and I want the commercial space industry in the United States to succeed and to lead.

To ensure continued success, it is important that we, as a Subcommittee with jurisdiction over commercial space, have a clear view of where the industry is, and where the industry is headed, the opportunities and challenges facing it, where and how the government intersects with commercial space, and what questions need to be answered as we carry out oversight of the government

as a user and enabler of commercial space activities. So before we delve into any one issue or activity, or segment of the industry specifically, we're starting today with an overview of commercial space.

In short, today's hearing is intended to be a "Commercial Space 101," if you will, to guide us into prioritizing the key issues and areas to examine as we look forward to subsequent hearings on commercial space during the 116th Congress. We've included a variety of voices on the panel, including those representing the breadth and diversity of the industry, and I look forward to your input today.

[The prepared statement of Chairwoman Horn follows:]

Good afternoon, and welcome to today's hearing on "The Commercial Space Landscape: Innovation, Market, and Policy." I especially want to welcome our distinguished witnesses. Thank you for being here.

From the Apollo program and the 50th anniversary of Apollo 11 that we just celebrated, to the Viking landers on Mars, the Landsat Earth observing satellites, and the Hubble Space Telescope, the private space sector has been a trusted partner in America's civil space program. While the Federal Government has taken the lead in R&D investments, design, development, testing, and construction of infrastructure and facilities, it has looked to the aerospace industry and its skilled workforce to implement Government mission requirements and build many of the spacecraft, instruments, vehicles, satellites, and systems that the Government has launched into space. This partnership has worked well, and the nation's successes in civil space owe much to the partnership between the Government and industry.

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Today, the commercial space industry is evolving. With these changes have come innovative technologies and operations and potential new services and capabilities that are infusing energyinto the commercial space industry. Private investors, venture capital, and other forms of investment are also expressing interest in the industry. According to one source, total investment in start-up space companies was at a record $3.2 billion in 2018, up from about $2.5 billion in 2017. We're on the precipice of what could be a ground-breaking shift in the technologies and services that affect our daily lives whether through new broadband communications services or information products derived from Earth remote sensing imagery.

I'm excited about the future of commercial space, and I want the United States commercial space industry to succeed and to lead. To ensure continued success, it's important that we, as the Subcommittee with jurisdiction over commercial space, have a clear view of where the industry is headed; the opportunities and challenges facing it; where and how the government intersects with commercial space; and what questions need to be answered as we carry out oversight of the government as a user and enabler of commercial space activities.

So before we delve into any one issue, activity, or segment of the industry, we're starting with an overview of commercial space. In short, today's hearing is intended to be a commercial space 101 that will guide us in prioritizing the key issues and areas to examine as we look forward to subsequent hearings on commercial space during the 116th Congress. We've included a variety of voices on the panel, including those representing the breadth and diversity of the industry, and I look forward to their input today.

Thank you.

Chairwoman HORN. Thank you, and the Chair now recognizes Ranking Member Babin for his opening statement.

Mr. BABIN. Thank you, Madam Chair, I appreciate it, and I want to say welcome, and thank you, to all our expert witnesses. Our nation's history in space has always featured partnerships with industry, from MacDonald Aircraft Corporation building the Mercury and the Gemini capsules, to Grumman building the Lunar Excursion Module for Apollo, or the United Space Alliance operating the Space Shuttle fleet, contractors and private sector have worked hand in hand with NASA (National Aeronautics and Space Administration) since the dawn of the space age. The future will be no different. In order to ensure that our Nation, government, military, industrial base, and society will continue to benefit from the unique opportunities that space affords, we must carefully craft a framework for the future, and that's why I was very pleased to see the Administration put forward Space Policy Directives (SPDs) 1, 2, and 3. SPD 1 directed NASA to lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the Solar System, and to bring back to Earth new knowledge and opportunities. I applaud this goal.

Space exploration will require collaboration with the private sector, just as it did 50 years ago, when Apollo 11 first landed on the Moon. As we chart a new course, NASA must find the right balance of how it procures hardware and services. If done correctly, NASA can leverage private sector investments to enable national exploration goals. If done poorly, public-private partnerships could end up simply as corporate welfare. We must carefully guard against subjecting our civil space enterprise to the uncertainty of the marketplace. To paraphrase a former Secretary of the Treasury, and Director of the National Economic Council, "the government is a poor venture capitalist." We must ensure that any cooperation is based on sound market projections, and that the private sector truly has skin in the game.

Turning to the other space policy directives related to commercial space, SPDs 2 and 3 directed agencies to streamline the regulation of private sector space activities, and provide better space situational awareness to space operators. In response to these directives, agencies are working to craft rules to cut red tape, while also providing certainty to the market, and meeting our domestic and international obligations. Despite the best intentions of the Administration, the first attempts by the Department of Transportation, the Department of Commerce, and the Federal Communications Commission (FCC) all seem to fall short, but this is not surprising. Regulatory path is fraught with uncertainty, beholden to the whims of unelected bureaucracies, and unresponsive to the needs of a rapidly innovating field. But there are a multitude of other constructs that can satisfy our obligations without stifling innovation, or smothering the embers of creativity. Standard-setting bodies, self-regulating organizations, carefully crafted public-private partnerships, and many other solutions should all be on the table.

How we craft space regulations is imperative to our future in space. Other states stand willing to challenge U.S. leadership in space through regulatory competition. In a global environment, in-

dividuals and companies are free to shop for the most attractive environment to claim as home. The implications of this choice go far beyond national pride. When space operators associate themselves with a particular nation, they bring jobs, economic growth, and tax revenue. They attract the best and brightest entrepreneurs, scientists, engineers, and technicians, and they create an incubator for future success. We cannot afford to scare these folks away to other nations, that will gladly provide a flag of convenience for them.

Aside from the established commercial space industries like communications, launch, and remote sensing, we must also consider new and unique activities, such as space to space remote sensing, commercial space-based signal collection, space resource utilization, satellite servicing, and commercial habitat services, amongst many others. None of these activities were seriously envisioned 50 years ago, and so it stands to reason that we have no idea what the next 50 years will have in store for us. And how we structure partnerships between our civil and commercial space sector, and how we will regulate our private-sector activities, is one of the fundamental space policy questions of our time. Whether or not our system of values will be carried by the future pioneers of outer space will very likely hinge on the degree to which America is able to unleash the awesome power of freedom, liberty, and protect against government overreach. I, for one, want to see the future of humanity in outer space guided by the principles of our great Nation.

The commercial space sector holds great promise, and I look forward to working with my colleagues to make sure that the commercial space policies, laws, and regulations that we adopt in the future will enable accomplishments just as amazing as those that we celebrated just last week. And I yield back.

[The prepared statement of Mr. Babin follows:]

Our nation's history in space has always featured partnerships with industry. From McDonnell Aircraft Corporation building the Mercury and Gemini capsules, to Grumman building the Lunar Excursion Module for Apollo, or the United Space Alliance operating the Space Shuttle fleet, contractors and the private sector have worked hand-in-hand with NASA since the dawn of the space age. The future will be no different. In order to ensure that our nation, government, military, industrial base, and society will continue to benefit from the unique opportunities that space affords, we must carefully craft a framework for the future.

That is why I was pleased to see the Administration put forward Space Policy Directives (SPD) 1, 2, and 3. SPD-1 directed NASA to "lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities." I applaud this goal. Space exploration will require collaboration with the private sector just as it did 50 years ago when Apollo 11 first landed on the Moon. As we chart a new course, NASA must find the right balance for how it procures hardware and services.

If done correctly, NASA can leverage private sector investments to enable national exploration goals. If done poorly, public-private partnerships could end up simply as corporate welfare. We must carefully guard against subjecting our civil space enterprise to the uncertainty of markets.

To paraphrase a former Secretary of the Treasury and Director of the National Economic Council, the government is a poor venture capitalist. We must ensure that any cooperation is based on sound market projections, and that the private sector truly has "skin in the game."

Turning to the other Space Policy Directives related to commercial space, SPD 2 and 3 directed agencies to streamline the regulation of private sector space activities, and provide better space situational awareness to space operators. In response to these directives, agencies are working to craft rules to cut red-tape while also pro-

viding certainty to the market and meeting our domestic and international obligations. Despite the best intentions of theAdministration, the first attempts by the Department of Transportation, the Department of Commerce, and the Federal Communication Commission all seem to fall short.

This is not surprising. The regulatory path is fraught with uncertainty, beholden to the whims of unelected bureaucracies, and unresponsive to the needs of a rapidly innovating field. But there are a multitude of other constructs that can satisfy our obligations without stifling innovation or smothering the embers of creativity. Standards-setting bodies, self-regulating organizations, carefully crafted public-private partnerships, and many other solutions should all be on the table.

How we craft space regulations is imperative to our future in space. Other states stand willing to challenge U.S. leadership in space through regulatory competition. In a global environment, individuals and companies are free to shop for the most attractive environment to claim as "home." The implications of this choice go far beyond national pride. When space operators associate themselves with a particular nation, they bring jobs, economic growth, and tax revenue. They attract the best and brightest entrepreneurs, scientists, engineers, and technicians, and create an incubator for future success. We cannot afford to scare these folks away to other nations that will gladly provide a flag of convenience.

Aside from the established commercial space industries like communications, launch, and remote sensing, we must also consider new and unique activities such as space-to-space remote sensing, commercial space-based signals collection, space resource utilization, satellite servicing, and commercial habitat services, amongst others. None of these activities were seriously envisioned 50 years ago, so it stands to reason that we have no idea what the next 50 years will have in store.

How we structure partnerships between our civil and commercial space sector, and how will regulate our private sector activities is one of the fundamental space policy questions of our time. Whether or not our system of values will be carried by the future pioneers of outer space will likely hinge on the degree to which America is able to unleash the awesome power of freedom and protect against government overreach. I for one want to see the future of humanity in outer space guided by the principles of our great nation. The commercial space sector holds great promise. I look forward to working with my colleagues to make sure the commercial space policies, laws, and regulations we adopt in the future enable accomplishments just as amazing as those we celebrated last week.

Chairwoman HORN. If there are Members who wish to submit additional opening statements, your statements will be added to the record at this point.

[The prepared statement of Chairwoman Johnson follows:]

Good afternoon, and thank you Chairwoman Horn for holding this hearing on the ″Commercial Space Landscape.″ I also want to welcome our witnesses. It's good to have you here and we appreciate your participation.

Since the 1980s, this Committee has been at the forefront of guiding the evolution of the commercial space industry. The legislation it has put forward--and had enacted into law--has been instrumental in providing the framework for what are now robust and growing commercial space launch and space-based remote sensing industries.

NASA Authorization Acts that this Committee has led have encouraged and authorized government-commercial activities, including the commercial resupply services that deliver cargo and supplies to the International Space Station. In addition, many of our government R&D investments have translated into commercial opportunities. This is one of many positive outcomes of our taxpayers' investments.

In short, I strongly support the future growth and success of the United States commercial space industry. I also want this Committee to continue to be on the cutting-edge of enabling commercial space and providing carefully considered policy guidance to support it. In the waning hours of the last Congress, there were attempts to pass commercial space legislation. That was a rushed effort and not the optimal way to legislate on such important matters as the future of commercial space. We need to get it right.

So I am pleased, Madame Chair, that you are holding this overview hearing, because a lot is changing and we need to be fully informed before developing policy. The Administration is proposing new regulations for commercial space launch and reentry, and also for commercial space-based remote sensing. We need to understand those changes and any implications of them. We also need to understand the government's role in commercial space, the appropriate ways in which the government can leverage commercial capabilities, and any associated risks to the taxpayer.

In closing, I want to commend our commercial space companies that are making such impressive progress. There's not a week that goes by without reading about a significant milestone in a commercial program, the deployment of a new capability in space, or an innovative plan that is attracting commercial investment.

Well, it's clear there is a lot to discuss today, and I look forward to our witnesses' testimony. Thank you, and I yield back.

Chairwoman HORN. Thank you very much, Ranking Member, excuse me, and welcome, again, everyone. I will now introduce our distinguished panel of witnesses, beginning Dr. Bhavya Lal. Dr. Lal is a research staff member at the Institute for Defense Analysis, Science, and Technology Policy Institute. There Dr. Lal leads strategy, technology assessment, and policy studies, and analysis for Federal space-oriented agencies. Dr. Lal regularly serves on the National Academy of Science committees, and is currently serving on the NOAA (National Oceanic and Atmospheric Administration) Advisory Committee on Commercial Remote Sensing. Dr. Lal holds a bachelor's degree and master's degree in nuclear engineering from MIT, and a master's degree from MIT's Technology and Policy Program, and a doctoral degree in Public Policy and Public Administration from George Washington University. Welcome, Dr. Lal.

Our next witness is Carissa Christensen. Ms. Christensen is the founder and CEO of Bryce Space and Technology, an analytics and engineering firm with expertise in space, cyber, and advanced R&D. She sits on the board of the Aerospace Center for Space Policy and Strategy, and serves on the National Research Council's Space Technology Industry-Government-University Roundtable advisory group to NASA. That is a mouthful. Ms. Christensen holds a Public Policy Degree from Harvard University. She also completed the general course in government at the London School of Economics, and was a Douglas Scholar at Rutgers University. Welcome, Ms. Christensen.

Our next witness is Mr. Eric Stallmer. Mr. Stallmer is the President of the Commercial Space Flight Federation (CSF), a trade organization dedicated to promoting the development of commercial space flight. He was recently appointed to the National Space Council User Advisory Group. Before working at CSF, Mr. Stallmer served as the Vice President of Government Relations at Analytical Graphics, Inc., and Mr. Stallmer has a bachelor's degree in political science and history from Mount Saint Mary College, and a master's degree in public administration from George Mason University. Welcome, Mr. Stallmer.

Our next witness is Mr. Mike French. Mr. French is the Vice President for Space Systems at the Aerospace Industries Association, or AIA, a trade association representing manufacturers and suppliers of the U.S. aerospace industry. He previously served as the Senior Vice President for Commercial Space at Bryce Space and Technology. Mr. French held several Federal Government positions, most recently serving as NASA's Chief of Staff, where he received NASA's Distinguished Service Medal for his service. Mr. French holds a bachelor of science in business administration from the University of California Berkeley, and a juris doctorate from Harvard Law School. Welcome, Mr. French.

And our final witness today is Ms. Laura Montgomery. Ms. Montgomery teaches space law at Catholic University Columbus School of Law. She also writes and edits the law blog, Ground

Based Space Matters. Previously Ms. Montgomery spent over 2 decades with the Federal Aviation Administration (FAA), serving as the manager of the Space Law Branch in the Office of Chief Counsel and as the FAA's Senior Attorney for Commercial Space Transportation. Ms. Montgomery received her bachelor degree from the University of Virginia, and her law degree at the University of Pennsylvania. Welcome, Ms. Montgomery.

And before we begin our testimony and questions, I will take a moment to introduce a letter that has been submitted for the record, we'll submit it into the record at this time, from the Coalition for Deep Space Exploration on the NPR, the Notice of Proposed Rulemaking. And we'll submit that to the record at this time.

And now, as our witnesses, you should know you will each have 5 minutes for your spoken testimony. Your written testimony, of course, will be added into the record, and can be more expansive, for the hearing. And when you have completed your spoken testimony, we'll begin with questions. Each Member will have 5 minutes to question the panel, and we will go in the same order of introduction, so we'll start with Dr. Lal. Dr. Lal, you're recognized for 5 minutes.

TESTIMONY OF DR. BHAVYA LAL, RESEARCH STAFF MEMBER, IDA SCIENCE AND TECHNOLOGY POLICY INSTITUTE

Dr. LAL. Madam Chair, Ranking Member Babin, and distinguished Members of the Subcommittee, thank you for the opportunity to testify today. In my remarks, I would like to address three questions. First, what is commercial space? Second, what benefits does it bring? And third, how can the government best leverage commercial space?

So what's commercial space? The term is used loosely, and generally brought up in three different contexts. Some people use it to describe commercial companies that are often, but not always, startups. These companies put angel, or venture funding, or their own resources, at risk to build space systems. For others it refers to commercial approaches, which are often fixed-price, milestone-based contracts typically used in our market-based economy, but much less so by space agencies. Yet others refer to it in the context of firms having primarily private customers, or customers other than the U.S. Government. Thus, in using the term commercial space, most people are alluding either to innovative startups, non-traditional contracting mechanisms, or non-governmental customers.

The second question is, what benefit does commercial space bring? Commercial style contracts, such as the one mentioned above, as well as private investors with skin in the game, as Representative Babin said, incentivize two kinds of behaviors, rapid development, and a focus on cost reduction. As a result, the most important benefit commercial space brings is lower cost, although at times this is at the expense of performance and reliability. Given the potential for cost savings, commercial approaches are not just being considered in the launch sector, where cost savings have been well documented, but also in other sectors that actually used to be considered the sole province of the government. Examples in-

clude SSA, or space situational awareness, space nuclear power, on-orbit servicing, assembly, and manufacturing, and even deep space science.

Commercial space has brought more than cost savings into the space sector. In some cases, commercial capabilities have surpassed, or are entirely complementary to government ones. Commercial companies have leveraged innovations such as miniaturization, satellite mass production, and use of commercial off-the-shelf (COTS) components to produce capable, lightweight satellites. These satellites can be simultaneously deployed, meaning that many hundreds can be launched and operated, and provide 'round-the-clock simultaneous multi-point imagery of any place on Earth, or in space, for scientific national security and commercial purposes. This coverage is obviously impractical with traditional satellites.

My last point on this question is that, despite the high levels of innovation and cost-effectiveness, if you draw the system boundaries around space-based activities, the principle customers of commercial space today, and in the near term, are governments, not private, and there are only a handful of exceptions, such as satellite communication and satellite TV, that are paid for by private entities. Lack of demand in the private sector constrains robust development and growth in the commercial space sector.

The final question is, how can the government best leverage commercial space? Our research has shown that government purchases of products and services from commercial companies, or using commercial approaches, has the twin benefit of reducing cost, accelerating the development of many government space programs, as well as fostering the growth of the space sector, and promoting the industrialization of space. In light of potential government benefits and commercial needs, we have two recommendations. First, at a conceptual level, space agencies should design mission plans and architectures that are sufficiently flexible, such that when commercial capabilities reach adequate readiness levels, they can be incorporated in these missions and architectures. For example, several companies are exploring water extraction systems on the Moon, and other companies are investing in technologies and systems related to space-based propellant depots and tugs in low-Earth orbit (LEO). NASA should have architectures in place so, when these capabilities are commercially available, the government can quickly transition their operations to exploit them.

Second, and more concretely, space agencies should consider, as a norm, rather than as an exception, fixed-price, milestone-based contracts when purchasing space goods and services. In some cases, a cost-plus contract is necessary and appropriate, for example, for certain high-risk developmental items. But more often than not fixed-price contracts suffice, and allow companies to propose their own innovative solutions. The overarching question, therefore, when considering commercial solutions that must be asked is, would we consider accepting, in cases where it makes sense, an 80 percent solution at half the cost, and double the speed? I'd be happy to expand on any of these points. Thank you for your time.

[The prepared statement of Dr. Lal follows:]

THE COMMERCIAL SPACE LANDSCAPE: INNOVATION, MARKET, AND POLICY

Testimony before the Committee on Science, Space, and Technology
Subcommittee on Space and Aeronautics
U.S. House of Representatives
July 25, 2019

Dr. Bhavya Lal, IDA Science and Technology Policy Institute (STPI)

Madam Chair, Ranking Member Babin, and Distinguished Members. Thank you for the opportunity to testify today. In my remarks today, I would like to address three questions: First, what is commercial space? Second, what benefits does it bring? And third, how can the government best leverage commercial space?

First, what is commercial space? The term is used loosely and generally refers to two distinct concepts. Sometimes it is used to describe commercial *companies*, that are often but not always, startups. These companies put angel or venture funding or their own resources at risk to build space systems. And at other times, it refers to commercial *approaches*, which are often fixed-price, milestone-based contracts typically used in our market-based economy, but less often by space agencies. Thus, in using the term commercial space, most people are alluding either to innovative start-ups or to non-traditional contracting mechanisms.

The second question is what benefits does commercial space bring? Commercial-style contracts such as the one mentioned above, as well as private investors with "skin in the game," incentivize two kinds of behaviors: rapid development and a focus on cost reduction. As a result, the most important benefit commercial space brings to the space sector is low-cost, although at times, this is at the expense of performance and reliability. Commercially built rockets offer an illustration of this tradeoff. The Falcon Heavy may have less thrust at liftoff than, say the Space Shuttle, but it is also less than one tenth as expensive per kilogram of payload launched to low Earth orbit (SpaceX and NASA websites). Given the potential for cost-savings, commercial approaches are not just being considered in the launch sector, but also in other sectors such as space situational awareness or SSA; space nuclear power; on-orbit servicing assembly and manufacturing; and even deep space exploration.

Commercial space has brought more than cost reductions into the space sector. Commercial companies have leveraged innovations such as miniaturization, satellite mass-production, and use of commercial off-the shelf components, to produce capable lightweight satellites. These satellites can be simultaneously deployed, meaning that many hundreds can be launched and operated, and provide round the clock simultaneous multi-point imagery of any place on Earth or in space for scientific, national security, and commercial purposes. This coverage is impractical with traditional satellites.

In some cases, commercial capabilities have surpassed government ones. For example, data collected by commercial sensors enables a catalogue of objects in the geosynchronous orbit that includes objects that may be unknown to the government. Additionally, commercial networks

have enough capacity to provide persistent tracking coverage of all objects in GEO for the majority of the day at a rate of multiple observations per minute. Government systems may be able to match either the breadth or speed of this coverage, but not both.

My last point on this topic is that despite the high levels of innovation and cost-effectiveness, if you draw the system boundaries around space-based activities, the principal customers of commercial space today and in the near term are governments not private. Lack of demand in the private sector constrains robust development and growth in the commercial space sector.

The final question is how can the government best leverage commercial space? Our research has shown that government purchases of products and services from commercial companies using commercial approaches has the twin benefit of (1) reducing costs and accelerating the development of many government space systems, as well as (2) fostering the growth of the space sector and promoting the industrialization of space.

In light of potential government benefits and commercial needs, we have two recommendations. At a conceptual level, space agencies should design mission plans and architectures that are sufficiently flexible such that when commercial capabilities reach adequate readiness levels, they can be incorporated in these missions and architectures. For example, there are several companies exploring water extraction systems on the Moon, as well as companies investing in technologies and systems related to space-based propellant depots and tugs. NASA or DOD should have architectures is place so when these capabilities are commercially available, the government can quickly transition their operations to exploit them.

Second, and more concretely, space agencies should consider *as a norm rather than an exception,* fixed-price, milestone-based contracts when purchasing space goods and services. In some cases, a cost-plus contract is necessary. But more often than not, fixed-price contracts suffice, and allow companies to propose their own innovative solutions. The question is would space agencies consider accepting, in cases where it makes sense (I do want to reinforce this), an 80 percent solution at half the cost and double the speed?

I'd be happy to expand on any of my points above. Thank you for your time.

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BHAVYA LAL BIODATA SHEET

Bhavya Lal leads strategy, technology assessment, and policy studies and analyses at the IDA Science and Technology Policy Institute (STPI) for the White House Office of Science and Technology Policy (OSTP), the National Space Council, and Federal space-oriented organizations including NASA, the Department of Defense and the Intelligence Community. She has applied her expertise in engineering systems and innovation theory and practice to topics in space, with particular focus on commercial activities, especially related to space nuclear power, on-orbit servicing assembly and manufacturing, small satellites, human exploration, and space science.

She is currently serving on a National Academy of Science (NAS) committee on assessing the relative merits of infrared vs. visual observations by a space-based telescope to detect and characterize near Earth objects. She recently co-chaired a NAS Committee on the State of U.S. Electronic Parts Radiation Testing Infrastructure for Space Applications, and was previously vice-chair of the NAS committee on Achieving Science Goals with CubeSats, and member of the committee on 3D Printing in Space.

She is serving a second term on the NOAA Advisory Committee on Commercial Remote Sensing (ACCRES), and participated on the UN Committee on Space Research (COSPAR) to develop an international scientific roadmap for small satellites. She co-organizes a seminar series on space history and policy with the Smithsonian National Air and Space Museum. She co-founded and is co-chair of the policy track of the American Nuclear Society's annual conference on emerging technologies and space nuclear power.

Before joining STPI, Dr. Lal was president of C-STPS LLC, a science and technology policy research and consulting firm. Prior to that, she was the Director of the Center for Science and Technology Policy Studies at Abt Associates. Dr. Lal holds B.S. and M.S. degrees in nuclear engineering from the Massachusetts Institute of Technology (MIT), a second M.S. from MIT's Technology and Policy Program, and a Ph.D. in Public Policy and Public Administration from George Washington University.

Chairwoman HORN. Thank you, Dr. Lal. Ms. Christensen?

TESTIMONY OF CARISSA CHRISTENSEN,
CHIEF EXECUTIVE OFFICER,
BRYCE SPACE AND TECHNOLOGY

Ms. CHRISTENSEN. Chairwoman Horn, Ranking Member Babin, and distinguished Members of the Subcommittee, thank you for inviting me here to discuss the commercial space landscape. I've provided independent analysis of space activities for more than 3 decades, and I've built my career and my business on the principle that evidence-based objectivity and rigor are critical to effective decisionmaking, and I'm pleased to share my analysis with the Committee. Today I'll talk about three elements of commercial space activities: The current commercial space economy, recent investment in emerging space ventures, and the important implications of this innovation for government.

The commercial space economy has existed for decades, dominated by well-established satellite operators providing television, Internet, and many other services. Launch and satellite manufacturing enabled those services. Considering key industry sectors, as well as government space budgets, the value of the global space economy is about $360 billion. A quarter of that is government space budgets, and half of that is the U.S. The remaining global space economy, more than $275 billion in 2018, is dominated by revenues from satellite services and related products. Two large markets, direct to home satellite television and location and mapping based on the U.S. Global Positioning System and other navigation satellites, are by far the biggest contributors to total industry revenue at about $100 billion each. Satellite service revenues overall have been growing at about the rate as the global economy, roughly 2 to 3 percent. The outlook for established services is fairly stable. I'll talk in a moment about innovative satellite startups. In general my expectation is that those startups will tend to augment, rather than replace, current capabilities.

Looking toward the future, emerging space businesses seek to expand the commercial landscape. Today we're seeing unprecedented numbers of new space businesses, enabled by three factors. In particular: Very small satellites, new markets, from satellite services to in orbit activities, and new investors. Billionaire super-angel investors and venture capital firms have invested between $2 and $3 billion a year since 2015 in emerging space ventures, with the majority invested in U.S. companies. While a few companies, SpaceX, Blue Origin, and OneWeb, account for a substantial portion of this investment, it has resulted in more than 250 new space firms. Venture investment is relatively new to the space industry. These investors bring risk tolerance that allows ventures to pursue unproven business plans in riskier markets. Generally, more than three-quarters of venture-funded firms fail. Regardless of the success or failure, I want to note that capital being directed to technology and capability development today may result in valuable outcomes for the government and industry. Looking at these new businesses, they include broadband satellite service providers, launch companies, companies seeking to operate in low-Earth orbit, and many others.

New companies in low-Earth orbit seek to offer a variety of services, including manufacturing, transportation, and so on. Based on today's demand signals, these businesses have a limited customer base. The most promising markets are human accommodations, especially for government astronauts, and on-orbit servicing, assembly, and manufacturing. The exploration activities of the U.S. Government and its partners will have a significant effect on most LEO businesses. These new firms create both opportunities and challenges for the government. The government is a longstanding customer of commercial space capabilities, and helps facilitate today's commercial space markets. The government has an opportunity to leverage emerging commercial space companies to help it do more, and spend less. However, the price of leveraging this investor-funded dynamic innovation is uncertainty. The government must carefully consider how to take best advantage of this opportunity, while assuring long-term access to mission-critical services.

I appreciate the opportunity to share my analysis and findings, and I very much look forward to your questions.

[The prepared statement of Ms. Christensen follows:]

Testimony of Carissa Christensen

CEO, Bryce Space and Technology

Before the Committee on Science, Space and Technology
Subcommittee on Space and Aeronautics
United States House of Representatives
Thursday, July 25, 2019

Chairwoman Horn, Ranking Member Babin, and distinguished members of the Subcommittee—thank you for inviting me to discuss the commercial space landscape. I have provided independent analysis of space activities to governments, industry, and investors for more than three decades. I have built my career and my businesses on the principle that evidence-based objectivity and rigor are critical to effective decision-making and I am pleased to share my analysis with the Committee.

Today, I will discuss three key elements of today's commercial space activities: the composition of the current commercial space economy, recent investment and emerging space ventures, and important implications of this innovation for the government.

Current Space Economy

The commercial space economy has existed for decades, dominated by well-established satellite operators providing television, internet, and many other services. Launch and satellite manufacturing enable these satellite services.

Considering key industry sectors as well as government space budgets, the value of the global space economy is about $360B, based on a business-focused framework developed by Bryce. This framework is limited to space businesses that directly interact with the space sector, which is the most useful information for our discussion today. This is a widely used definition of the space economy. (There are other ways the space economy can be viewed; for example, looking more narrowly at solely the space hardware segment or more broadly at related industries enabled by space capabilities.)

The $360 billion space economy consists of government budgets and commercial revenue. Government budgets comprise just under one-quarter of the global space economy, about $80 billion in 2018. The United States government is responsible for about half of that, through NASA, the space activities of military and intelligence agencies and the National Oceanic and Atmospheric Administration, and regulators such as the Office of Commercial Space Transportation, the Office of Space Commerce, and the Federal Communications Commission.

The remaining global space economy, more than $275 billion in 2018, is dominated by revenue from satellite services and related products. Two large markets, direct-to-home satellite television, and location and mapping based on the US Global Positioning System (GPS) and other navigation satellites, are by far the biggest contributors to total industry revenue, at around $100 billion each.

Satellite services revenues have, overall, been growing at about the same rate as the global economy, roughly 2 to 3%. Some areas have seen higher growth rates, such as mobile services, satellite

broadband, and satellite radio. Other areas have grown more slowly or even seen slight declines; for example, satellite television, similar to terrestrial cable television, has seen the effects of changing television viewing patterns.

The outlook for established satellite services businesses is fairly stable, taking into account both these growth areas and demand pressures. I'll talk in a moment about innovative satellite start-ups; in general, my expectation is that those providers will tend to augment rather than replace current capabilities.

Finally, I'll note that satellite manufacturing and launch revenues combined are about 10% of satellite service revenues. Satellite manufacturing and launch are critical to enabling the satellite industry, but the much higher revenues from services drive the global space economy. Today, satellite manufacturing and launch revenue mainly reflect large satellites that often cost hundreds of millions of dollars.

Satellite services provided by large satellites are the primary revenue driver in today's commercial space economy. In addition, the space economy is opening to commercial human spaceflight and other new capabilities.

Emerging Space Economy

Looking toward the future, emerging space businesses seek to expand the commercial space landscape.

Today we are seeing unprecedented numbers of new space businesses, enabled by three main factors.

New technology. Technology has reduced the cost of space activities, through advanced computing, miniaturized electronics, additive manufacturing, and many other fields. A particularly important development has been small satellites, which are the size of microwaves or dishwashers instead of the size of cars or buses. These smaller satellites have a lower entry price, which enables new satellite architectures and services. In addition, technology advances have also reduced launch costs and increased capability.

New markets. Companies are pursuing new space markets including many types of satellite service, a range of activities in orbit, human spaceflight for tourism and research, and the use of space resources. The government is a customer, or potential customer, for many of these emerging markets.

New investors. New technology and new markets have attracted new investors. Billionaire super-angel investors and venture capital firms have invested between two and three billion dollars a year since 2015 in emerging space ventures, with the majority invested in US companies. While a few companies (SpaceX, Blue Origin, and OneWeb) account for a substantial proportion of this investment, venture investor support of startups has resulted in hundreds of new space firms. Venture investment is relatively new to the space industry; the smaller investment required for small satellite systems is an important reason venture investors have entered the space arena. These investors bring risk tolerance that allows ventures to pursue unproven business plans in riskier markets.

As a result of this more risk tolerant investment capital, many angel- and venture-funded companies will not succeed – across industries, more than 75% of venture capital funded firms fail. Regardless of the success or failure of individual space ventures, capital being directed to technology and capability development may result in valuable outcomes for the industry and the government.

Venture and other recent investment have resulted in about 250 angel- and venture-funded space companies, with the majority based in the US. These companies include:

- More than 50 satellite companies
- Nearly 40 launch companies
- Dozens of companies pursuing new space businesses in low Earth orbit and beyond, even including the moon
- Over 100 in other areas

Among these businesses are satellite service providers, for example, that seek to provide global broadband service using large constellations of small satellites, often to compete with terrestrial offerings on performance and price. Others want to provide business and policy insight based on unique imagery fused with other data and powered by advanced data analytics.

As I have described, these ambitious goals come with significant business risk. While start-up satellite companies have targeted more than 20,000 small satellites in the next decade – more than ten times the number of satellites currently in orbit – many of these satellites will not deploy. Some ventures will not reach business maturity, while others will deploy some satellites but not close their business case over the long term.

Another example of emerging space business is small launch providers seeking to provide vehicles that enable small satellites to economically fly direct, rather than flying as secondary passengers on a larger vehicle. Because it can cost appreciably less to fly as a passenger on a larger vehicle, a critical business challenge for small launch providers is building a sufficient customer base that values schedule control and autonomy over price per kilogram. Government customers seeking responsive launch or dedicated launch for unique science missions are increasingly looking to be important customers for small launchers.

Finally, companies seek to operate in low Earth orbit (LEO), offering manufacturing, transportation and servicing, human accommodations, and other capabilities. Based on today's demand signals, these businesses have a limited customer base. The most promising markets are human accommodations, especially for government astronauts, and on-orbit servicing, assembly, and manufacturing. The exploration activities of the US government and its partners will have significant effect on most LEO businesses.

Government Engagement

These new firms create opportunities and challenges for government.

The government is a long-standing customer of commercial space capabilities and helped facilitate today's commercial space markets. The government has an opportunity to leverage emerging commercial space companies to help it to do more and spend less. However, the price of leveraging this investor-funded, dynamic innovation is uncertainty. The government must carefully consider how to best take advantage of this opportunity while ensuring long-term access to mission critical services.

Uncertainty will affect the government's decisions regarding acquiring products or services, sometimes creating concerns about future availability. Uncertainty also makes decisions regarding regulatory

structures and content more complex. And uncertainty creates situations in which government support to reduce risk is often sought, such as through development programs or serving as a key customer.

As diverse US government agencies seek the best outcome for their mission objectives, the government will be well served by being a flexible and informed customer and partner with industry. Implementing acquisition processes and partnering mechanisms that recognize and specifically address this business uncertainty will help the government benefit while managing risk.

I appreciate the opportunity to share my analysis and findings and I look forward to your questions.

Carissa Christensen Bio

Carissa Christensen is an internationally recognized expert on commercial space and the interplay of government, military, and commercial activities in the aerospace sector.

A frequent speaker and author on space and satellite trends, Ms. Christensen is a strategic advisor to government and commercial clients. She serves on the National Research Council Space Technology Industry-Government-University Roundtable (STIGUR) advisory group to NASA. She is a Senior Advisor to the US Air Force Schriever Wargame. She also sits on the board of the Aerospace Corporation Center for Space Policy and Strategy.

Ms. Christensen is the founder and CEO of Bryce Space and Technology, a leading analytics firm. She also co-founded QxBranch, LLC, a quantum computing software firm recently acquired by Rigetti Computing. Prior to founding Bryce, Christensen co-founded and was a Managing Partner of The Tauri Group, LLC and was a partner in CenTauri Solutions, LLC, acquired by CSC in 2010.

Ms. Christensen also serves an expert witness on space markets and business.

Ms. Christensen holds a Master of Public Policy degree from Harvard University's Kennedy School of Government, where she specialized in science and technology policy. She also completed the General Course in Government at the London School of Economics and was a Douglass Scholar at Rutgers University.

Ms. Christensen is a Fellow of the American Institute of Aeronautics and Astronautics.

Chairwoman HORN. Thank you, Ms. Christensen. Mr. Stallmer?

TESTIMONY OF ERIC W. STALLMER,
PRESIDENT, COMMERCIAL SPACEFLIGHT FEDERATION

Mr. STALLMER. Chairwoman Horn, Ranking Member Babin, and distinguished Members of the Subcommittee, thank you for inviting the Commercial Space Flight Federation back to discuss the progress of the U.S. commercial space industry. From the *Commercial Space Launch Act of 1984* through today, this Committee has steadfastly supported the unleashing of American free enterprise to develop the economic opportunities of space. Every major commercial space policy law was born here, in this room, and we hope you understand how vital the bipartisanship work that this Committee, and the House, has been to our industry's growing success.

The United States is undergoing a Renaissance in space led by commercial enterprise. Since 2009, investors have supported over 476 private space companies, with over $22 billion in private capital. In my written statement, I outlined several of the commercial space industry's recent major milestones, which sets the stage for even greater accomplishments. As NASA continues to drive the frontier onward with groundbreaking research, the commercial sector is making space affordable and accessible. We are in the defining moments of a new era of space exploration and development, and it's critical that we work together to improve our policy environment to ensure continued U.S. leadership in space.

Accordingly, I offer the following recommendations. We need to streamline our Federal regulations. We compliment the FAA for getting the proposed rule out fairly, delayed only by the government shutdown. Fairly quickly, I should say. Unfortunately, instead of one giant leap forward, the FAA seems to have taken only a cautious half step toward regulatory regime needed by the growing and diverse new space transportation providers and their many users. The 580-page NPRM, plus over 1,000 pages of supporting documents, is very complex, and frequently confusing. Its preamble cites many of the right goals, but the proposed regulations do not deliver on them. Most current or prospective FAA space licensees have determined that the NPRM, in some ways, are worse than today's obsolete rules.

The NPRM is not adequately performance-based, like it was intended. It adds new burdens and cost, it's confusing, and relies on missing documents. It lacks the flexibility to allow for innovation. It's anti-competitive in many ways, creating new burdens to entry for users. And it attempts to fix things that were not broken, and add even more burden to the users. That is why all the license applicants in the Commercial Space Flight Federation, including our largest spaceports, plus several other entrepreneurial companies, all want DOT (Department of Transportation) and FAA, using the—all the—using the many available mechanisms for active industry interaction, to develop and publish a supplemental Notice of Proposed Rulemaking. We appreciate the Administration's eagerness to reform the FAA's obsolete rules, but we really need to get this right. The companies that are growing, innovating, and improving America's access to space are requesting major revisions to this NPRM. So that—the FAA must take the time to engage with

everyone, including the newest members of our industry, so the agency can craft rules for the future.

We also must expand on NASA's use of COTS-like partnerships with the commercial industry for human exploration. By even most conservative analysis, the COTS commercial cargo public-private partnership saved NASA hundreds of millions of dollars. Why? Commercial space is underpinned by pay-for-performance, fixed-price contracts, agile and creative development teams, greater flexibility and risk tolerance, private capital investment, and more and more intensive innovation.

This is not CSF's opinion, but the conclusion of numerous independent reviews of program. For example, in 2014 a report praised the COTS ISS (International Space Station) cargo public-private partnership, and I quote, "because these were partnerships, not traditional contracts. NASA leveraged its $800 million COTS budget with partner funds. This resulted in two new U.S. medium-class launch vehicles, and two automated cargo spacecraft, and demonstrated the efficiency of such partnerships." A 2017 cost analysis review was more direct. The COTS development, and later operation commercial resupply services, are significant advances in affordability by any measure. Simply put, this approach works.

Last week we celebrated the historic achievements of our Nation a half century ago as we came together for a common goal in space, and it's right, and it's natural, to honor our past, but we should also be proud and excitement about the advancements we are achieving today, and what we can accomplish together tomorrow if we build a true partnership between government, including Congress, and the American people and their enterprise.

Chairwoman Horn, Ranking Member Babin, thank you for your invitation and attention. I look forward to your questions.

[The prepared statement of Mr. Stallmer follows:]

Testimony of Eric Stallmer
President,
Commercial Spaceflight Federation

Before the Committee on Science, Space, & Technology
Subcommittee on Space & Aeronautics
United States House of Representatives
Thursday, July 25, 2019

Chairwoman Horn, Ranking Member Babin, and distinguished members of the Subcommittee—thank you for inviting the Commercial Spaceflight Federation (CSF) to discuss our members' views on the state of the U.S. commercial space industry. We appreciate the Subcommittee's interest in exploring the commercial space landscape, and in developing policies that will allow the industry to keep expanding, innovating, and creating jobs. Given the increase in the cadence and diversity of U.S. launches, technological advances like reusability and networked smallsats, and the expanding scope of commercial space activities, this hearing is timely and necessary.

CSF is the leading national trade association for the commercial space industry, with more than 85 member companies and organizations across the United States. Founded in 2006, CSF is focused on laying the foundation for a sustainable space economy and democratizing access to space for scientists, students, civilians, and businesses. CSF members are responsible for the creation of thousands of high-tech domestic jobs driven by billions of dollars in investment. Through the promotion of technology innovation, CSF members are guiding the expansion of Earth's economic sphere, bolstering U.S. leadership in aerospace, and inspiring America's next generation of engineers, scientists, and explorers.

The United States established its leadership and dominance in space with government-funded and government-controlled space exploration. When President Eisenhower founded NASA and President Kennedy outlined a goal to send Americans to the Moon, there was no other choice; NASA literally had to invent whole new fields of technology, not just new hardware. The agency's accomplishments are a marvel for the ages, progressing from sending an American into space for the first time in 1961 to landing a crew on the Moon just eight years later.

Thanks to Congress' foresight and to NASA's leadership, pathfinding, and partnerships with the private sector in the decades since, the United States is undergoing a renaissance in space, led by commercial enterprise. NASA has co-invested in private development, used its purchasing power to serve as an anchor customer, and enabled private companies to develop, own, and operate their own human spaceflight hardware to serve both public and private needs. Because of the agency's partnerships with commercial industry, American companies today support critical space exploration and national security needs today, in addition to the commercial marketplace. And,

with this confidence in the market, investors have supported 476 private space companies with over $22 billion of private capital since 2009 alone.[1] NASA is leveraging that private capital to deliver key capabilities at great savings to taxpayers.

As NASA continues to drive the frontier outward with groundbreaking research in space, the commercial sector is making space affordable and accessible. To be precise: commercial space is underpinned by pay-for-performance, fixed-price contracts, agile and innovative development processes, flexibility and some level of risk tolerance, private capital co-investment, and more intensive innovation. By contrast, commercial space is not about cost-plus contracting, staid solutions, or routine requirements creep.

We are in the defining moments of the next era of space exploration and development. As commercial industry continues to develop new technologies at an accelerated pace, it is critical that we work together to improve our policy environment to ensure continued U.S. leadership in space. Accordingly, I offer the following recommendations:

1. Streamline federal regulations.
2. Expand NASA's use of COTS-like partnerships with commercial industry in its Moon to Mars effort and other programs.
3. Support a smooth LEO commercialization process that grows the LEO market over the long term, rather than sacrificing long-term growth for short-term revenue from the private sector.

I expand on each of these recommendations in the sections below.

I. A Brief History of Commercial Space Policy

- In 1984, the Commercial Space Launch Act (CSLA) designated the Department of Transportation's (DOT) Office of Commercial Space Transportation (now FAA/AST) to encourage, facilitate, and license commercial expendable launch vehicle activities. CSLA set out statutory requirements for commercial space launch regulation and licensing. The Act defines the path for a commercial operator to receive a license if it meets defined requirements to surrounding public safety and safety of property, national security, and the foreign policy interests of the United States, but also that when they meet these requirements, the government shall issue them a license.
- In 1985, Congress updated the NASA Act of 1958 to specify that one of the agency's core missions is "[t]o seek and encourage, to the maximum extent possible, the fullest commercial use of space." This objective and the partnerships with industry that stemmed from it are a critical part of NASA's ongoing success in Earth orbit and beyond.
- In 1988, Congress amended the CSLA to establish the current third-party risk sharing regime between industry and the federal government. This "indemnification" regime represents a balance of protecting government and third parties from damage claims resulting from a failed launch, while also providing assurance to the industry, subject to appropriations. Indemnification allows companies to purchase reasonable insurance

[1]Proprietary Data, Space Angels, Q2 2019 Space Investment Quarterly.

policies that protect the federal government and themselves while competing against state-sponsored launch providers around the world that do not purchase insurance. In the 31 years since indemnification became law, no FAA-licensed commercial launch or reentry has ever resulted in casualties or substantial property damage to third parties, and therefore the government has never been asked to seek appropriations to pay any excess third party liability claims.

— In 1992, the Congress enacted the Land Remote Sensing Policy Act, creating a framework for the National Oceanic and Atmospheric Administration's (NOAA) licensing of commercial earth observation satellites.

— In 2000, Congress authorized in statute of the Office of Space Commerce within the Department of Commerce.

— The Commercial Space Launch Amendments Act (CSLAA) of 2004 further evolved space transportation regulations by defining suborbital launch systems, solidifying the process for licensing such vehicles, and allowing paying individuals to fly into space at their own risk. This legislation further ensured that FAA would continue its focus protecting public safety, while providing an extended period for the commercial spaceflight industry to innovate new approaches to human spaceflight without the fear of uninformed preemptive regulation to protect parties involved in the activity. Congress most recently extended this moratorium period in the Commercial Space Launch Competitiveness Act of 2015.

In addition, Democratic and Republican administrations have stressed the importance of the commercial space sector to the national interest. The current National Space Policy, issued by President Obama in 2010 and only slightly amended by Space Policy Directive 1 in 2017, directs the U.S. government to "purchase and use commercial space capabilities and services to the maximum practical extent," "refrain from conducting United States Government space activities that preclude, discourage, or compete with U.S. commercial space activities, unless required by national security or public safety," and "minimize, as much as possible, the regulatory burden for commercial space activities and ensure that the regulatory environment for licensing space activities is timely and responsive."[2]

In 2018, Space Policy Directive 2 began an active process of modernizing decades-old regulations for both space launch and reentry and commercial remote sensing. Those efforts are still underway, but industry appreciates both the Administration's and Congress' efforts to improve our regulatory regimes.

II. America's Commercial Space Sector Today

The United States is undergoing a renaissance in space, with commercial space enterprises playing a leading role. The commercial space industry's recent major milestones include:

— Last year, U.S. commercial space companies achieved an unprecedented 32 licensed orbital and suborbital launches as well as 14 licensed reentries. SpaceX conducted the

[2] Http://www.space.commerce.gov/policy/national-space-policy/

majority of those licensed activities, with 21 launches and 12 first stage landings. American commercial providers of medium-to-heavy lift launch services now represent a supermajority of global commercial launches each year.

— Over the past few years, there has been a surge of progress from dedicated small orbital class launch vehicles. In 2018, Rocket Lab conducted the first successful launch of its *Electron* rocket. Rocket Lab has already launched three more times in 2019, orbiting 35 satellites—including two for U.S. Special Operations Command. Relativity Space is building an autonomous rocket 3D printing factory in Mississippi, expanding capabilities at NASA's Stennis Space Center. Vector Launch and Vox Space (a Virgin Orbit subsidiary) have been selected to compete for DARPA's Launch Challenge. Virgin Orbit has completed several captive carries and one drop test of its LauncherOne vehicle with a 747 aircraft in preparation for launches to space in the near future.

— This growing demand has spurred the growth or emergence of commercial spaceports across the country, including Mid-Atlantic Regional Spaceport in Virginia, the Mojave Air and Space Port in California, Spaceport America in New Mexico, Colorado Air & Space Port, Camden County Spaceport in Georgia, and Space Florida's facilities at Cape Canaveral and NASA/KSC.

— A growing number of companies are restoring and expanding America's human spaceflight capabilities. This year SpaceX—in close partnership with NASA—will launch American astronauts to space on an all-American system, ending the country's drought in orbital human spaceflight capability left by the retirement of the Space Shuttle in 2011. Already, SpaceX and NASA conducted a successful flight qualification mission of the Crew Dragon spacecraft in March. Virgin Galactic successfully launched three spaceflight participants on its spacecraft—SpaceShipTwo—into space for the first time, reaching an apogee of 51.4 miles. Blue Origin has conducted a series of uncrewed suborbital test flights on its New Shepard vehicle and plans to conduct a crewed flight with crew soon. Both companies plan to fly spaceflight participants to space for revenue by the end of the year.

— American companies continue to make significant progress commercializing the International Space Station (ISS) and LEO.

  - Sierra Nevada Corporation's (SNC) Dream Chaser spacecraft—in an uncrewed cargo configuration—passed a key milestone in its development to be the third commercial cargo vehicle for the International Space Station.
  - NanoRacks is the largest private investor in the ISS, investing over $40 million to date. They have supported more than 800 payloads on the ISS to-date and has deployed over 230 cubesats through their commercially developed dispenser, in coordination with NASA. The company is also building the first-ever commercial airlock, which is manifested to launch on SpaceX-21, and planned to be operational within weeks of launch.
  - The ISS National Lab has facilitated more than $150 million in external, non-NASA funding to support the full ISS National Lab portfolio—a 50 percent increase in FY18.
  - Axiom, Bigelow Aerospace, and NanoRacks are developing commercial space habitats, and each has made major technical progress over the past year.
  - Made In Space, TechShot, and Space Tango continued to demonstrate additive manufacturing and other valuable commercial applications in microgravity.

— Planet, Blacksky, and Maxar Technologies deployed dozens of new commercial remote sensing satellites to orbit.

— Southwest Research Institute (SwRI), University of Colorado Boulder, and Maxar Technologies were selected by NASA to build three new lunar science and technology payloads to fly on future flights through NASA's Commercial Lunar Payload Services (CLPS) project. NASA selected three commercial Moon landing service providers that will deliver science and technology payloads under CLPS as part of the Artemis program.
— The first licensed flights to space of two American suborbital reusable launch vehicles: Blue Origin's New Shepard and Virgin Galactic's SpaceShipTwo. I emphasize the word licensed, because a license allows the company to earn revenue from the flight, unlike an experimental permit.
— World View performed its longest flight to date of its stratospheric balloon, demonstrating its ability to carry out missions traditionally reserved for satellites.
— And, in May, NASA has entered into partnerships with 11 companies—including CSF members Blue Origin, SpaceX, Sierra Nevada, and Maxar Technologies—to conduct advance development on human lunar lander concepts.

These recent achievements are just a few of many by the commercial spaceflight industry, and they set the stage for even greater accomplishments the rest of this year and beyond for a broad set of stakeholders.

III. Regulatory Framework

Launch and Reentry Regulatory Reform

Today's increasing rates of launches and reentries, together with innovative operations and continued industry diversification, are bringing to light new non-technical challenges. The first of these is the obsolete, burdensome, and duplicative body of regulations for launch and reentry. Today's rules were mostly crafted in the 1980s and 1990s, and they take a very narrow, prescriptive approach that does not support innovation in technology and operations, including changes that improve safety, efficiency and mission capacity.

Thanks to Space Policy Directive 2, last year the Federal Aviation Administration (FAA) Office of Commercial Space Transportation (AST) undertook an important and significant effort to revise its commercial space launch and reentry regulations. Last March an Aviation Rulemaking Committee (ARC) was chartered on Streamlined Launch and Reentry Licensing Requirements. This was an important step, because many industry experts believe that the best way to rewrite these regulations would be via a negotiated rulemaking. Unfortunately, the FAA only gave the ARC about 40 days to do its work, and then ignored the draft regulatory outline a majority of ARC members endorsed.

Ten months later, the FAA released its Notice of Proposed Rulemaking (NPRM), which is still open for public comment. The objectives for the NPRM were outlined in Presidential Space Policy Directive No. 2 (SPD-2). It stated, in relevant part:

The Secretary of Transportation shall consider the following:
(i) requiring a single license for all types of commercial space flight launch and re-entry operations; and

(ii) replacing prescriptive requirements in the commercial space flight launch and re-entry licensing process with performance-based criteria.

Importantly, neither SPD-2 nor the resulting NPRM has changed the level of public safety required for spaceflight activities. Nobody in industry (or government) is asking for a lower level of safety. The goal of SPD-2 and the NPRM is only to streamline the regulatory process and create a performance-based approach to regulating an innovative, evolving industry while encouraging it to become even safer.

We compliment the FAA for getting the proposed rule out fairly quickly, delayed only by the government shutdown. Unfortunately, instead of a giant leap forward, the FAA seems to have taken at best only a cautious half-step towards the regulatory regime America needs to enable the growth and diversity of new space transportation providers and their current and prospective users. The 580-page NPRM, plus over a thousand pages of supporting documents, is very complex and frequently confusing. It references several future Advisory Circulars which might explain some of the regulatory text, but these were not provided. Its preamble includes many of the right goals, but the actual proposed regulations do not achieve them. Worst of all, inputs that reflected the consensus position of a majority of the ARC's members were not included; indeed they were disregarded and the NPRM falsely claims they had only minority support.

Most current and prospective American commercial space licensees have determined that the FAA's NPRM is a regression from today's problematic regulations. As such, the Commercial Spaceflight Federation, and other entrepreneurial companies we have talked with, support the development of a Supplemental Notice of Proposed Rulemaking, and the active use by the DOT of many available appropriate mechanisms for interaction with stakeholders in developing this revised draft set of rules.

- **The NPRM is not performance-based.** Stakeholders recommended setting a performance level that would be supported by guidance documents (i.e. Advisory Circulars) that provide means of compliance that can be easily tailored to a diverse set of vehicles and operations. Instead, the NPRM includes highly-prescriptive requirements, such as for software and flight termination systems, that may undermine industry efforts to implement innovative approaches to improve safety.
- **The NPRM adds burdens and cost.** It contains a number of new regulations and requirements that do not appear to replace existing rules, but will increase the cost and effort necessary to comply rather than reduce and streamline the process - all without improving safety.
- **The NPRM is confusing and relies on missing documents.** Stakeholders have already highlighted in public comment dozens of areas where the rule lacks adequate clarity, supporting information (i.e. guidance documents), cost analysis, and adequate justification of new prescriptive regulatory requirements.
- **The NPRM lacks flexibility.** The rule misses the mark on allowing an applicant to work with the FAA to "tailor" the requirements to specific programs or to allow for new technology. The agency's approach risks being quickly outdated and discouraging innovation.

- **The NPRM is anti-competitive.** Technical requirements lack the clarity for even experienced launch operators to understand their purpose, while new and prescriptive requirements favor experienced operators to the detriment of new entrants. The NPRM also discourages operations from USG Ranges, thereby favoring operators who locate elsewhere, including outside the U.S.
- **The NPRM attempts to "fix" things that were not broken.** The NPRM's collision avoidance analysis process does not work with the current Air Force practice. This is one of many examples where the FAA's proposed rule conflicts with parts of the current licensing process that function effectively.

Historically, AST's regulations have been very specific and prescriptive.. The rules for expendable rockets were written that way partly because they were based on, or referenced, the Air Force's detailed safety procedures at the federal ranges, which go back to the days of the earliest ballistic missiles. But those same range rules are tailorable to the specific vehicle and mission proposed by a range user, while FAA regulations are not. As published, the NPRM creates active conflict between the FAA's rules and the Air Force's practices.

On the other hand, the regulations written in 2005 for reusable vehicles instead examines the safety of the launch or reentry system as a whole, independent of the specific technologies or operations concepts proposed. Whereas in 2017 and 2018 industry asked the FAA to expand on the performance-based reusable rules and provide guidance for different kinds of vehicles (e.g. expendable vs. reusable) – which would allow the current expandable rules to become guidance, and therefore not burden existing licensees – it appears that the FAA attempted to merge the prescriptive expendable and the reusable rules together, creating the flawed draft we have today.

The Administration's eagerness to advance this regulatory reform process is greatly appreciated; however, the FAA must prioritize substance over speed and respond to stakeholder's requests for significant revisions with a Supplemental NPRM. The FAA should take the time to interactively engage with stakeholders so they understand why this draft rule is such a disappointment before they publish a second draft. With a little time, and a lot of two-way communication, this reform effort can still create a regulatory regime that will keep our commercial space transportation industry on a safe and successful trajectory.

Remote Sensing Reform

Commercial Remote Sensing was born in the U.S. just as we were coming out of the Cold War, and the law and regulations the industry lives under were written with that mindset. Even so, the government all-too-often fails to live up to even those rules. In some cases, the government has taken years to respond, or has even never responded, to applications to use an innovative sensor, to improve available resolution, or sell data to a particular nation. Here, both the underlying statute and regulations need to be massively revised so that the government's actions are appropriate and transparent. CSF's members strongly support the approach taken by this Committee in 2017 with HR2809, the American Space Commerce Free Enterprise Act.

At the same time, we commend NOAA for not only issuing an initial set of proposed reforms to current remote sensing regulations, but for actively listening to industry, and in particular its Federal Advisory Committee, the Advisory Committee on Commercial Remote Sensing (ACCReS). With that said, the proposed rules by the Department of Commerce fails to address issues that would ensure U.S. leadership. For example:

- License requests can take months or years to approve, and there is little transparency into the decision making process.
- Current regulations allow for retroactive changes, creating uncertainty for U.S. companies.
- American firms must wait months for government approval to enter into large foreign imagery sales agreements, which results in a competitive disadvantage.

Not only does the NPRM not address current issues, but increases regulation and bureaucratic reporting. This is a step backwards for the industry.

Non-traditional Commerce

Finally, it's time for the federal government to create a minimalist process for approving new commercial space activities by U.S. companies that go beyond launch and reentry, telecommunications, and remote sensing. Again, HR 2809 provides a narrowly-tailored approach to government oversight of those activities, which is why CSF has repeatedly endorsed its passage.

IV. A Sustainable Deep Space Exploration Program

To ensure a sustainable, long-term civil space exploration portfolio that includes the Moon and Mars, the United States must further leverage the capabilities offered by the commercial space sector, including commercial heavy lift launch vehicles, the development of capable landers, the operation of robust deep space habitats and communications facilities, and routine transportation of astronauts and large cargo.

As this Subcommittee looks at how best to ensure the country's ongoing leadership in space, it must carefully review development and acquisition efforts to ensure responsible use of taxpayer dollars and to encourage, rather than hamper, rapid innovation. Specifically, public-private partnerships represent the most rapid and cost-effective path to expand the market in LEO and to develop and operate some elements of the exploration architecture to return to the Moon.

In these partnerships, NASA outlines high-level mission objectives and safety requirements, but does not dictate system designs. Companies are required to compete for awards and to self-invest; and they are paid on a fixed-price basis only upon achieving milestones. Further, these industry-led partnerships allow NASA to be one customer of many, stimulating a vibrant, commercial lunar economy. Already, due in part to the stability to the market that NASA brings

as a customer, numerous private companies are developing lunar systems and signing commercial business with customers around the world.

The Subcommittee should consider the Commercial Cargo program and its development effort—Commercial Orbital Transportation Services (COTS)—as the ideal model as it looks to structure its lunar lander and habitat programs. Specifically, a COTS-like program would:

- **Establish high-level requirements and encourage companies to execute against them** with creative, innovative, and cost-effective solutions, reducing "requirements creep" and encouraging new thinking. The COTS program required companies to meet a clear set of established safety and interface ISS requirements and high-level milestone requirements, rather than implementing overly-specified and ever-changing detailed Government requirements. This requires the Government customer to tell companies what they need to be done, rather than prescribing how to do it.
- **Use firm, fixed-priced, pay-for-performance, milestone based agreements or contracts**, creating proper incentives on the companies to execute toward successful conclusion, and discourage continuous Government requirement changes that add costs and delay schedules. Pay-for-performance creates proper incentives on both sides of the Government/company relationship.
- **Maximize competition**, which is critical to drive value and performance, and improve quality of service to the customer.
- **Require a significant private capital contribution to the overall program.** The COTS agreements required commercial partners to share costs and provide a significant percentage of the overall total investment, resulting in lower costs to the Government and high incentives for commercial firms to drive toward operational success to generate revenue and recoup their investment.
- **Tolerate programmatic risk, and allow easy termination for failure.** The flexibility to terminate contracts and rapidly "stop the bleeding" on non-functional programs is one that is largely lost when applied to traditional FAR-based contracts.
- **Encourage new, non-traditional companies to work with NASA.** Due to the complexity and cost associated with conforming to traditional FAR-baed contract requirements, start-up companies with small teams and less experience interfacing with the complex regulatory and contractual environment associated with U.S. Government are often deterred from participating at all. As a result, the Government is often not at the cutting edge of new commercial technology offerings. The use of COTS-like contracts can help enable such firms to do business with the Government.
- **Facilitate the development of new markets**, and leverage market-driven pricing to support U.S. Government requirements and missions.

By even the most conservative independent evaluation, the COTS Commercial Cargo public-private partnership saved the agency hundreds of millions of dollars and allowed NASA to redirect those savings towards funding its other priorities, including earth observation and deep space exploration.

Numerous independent reviews of the program have repeatedly praised this partnership for its significant savings for the taxpayer. In August 2011, NASA, using the NASA-Air Force Cost Model (NAFCOM), determined that had the agency saved between $1 billion and almost $4 billion by using the COTS model as compared to a traditional procurement approach.

A 2014 NASA report further praised the program's use of innovative, flexible Space Act Agreement (SAA) development arrangements: "[b]ecause these were partnerships, not traditional contracts, NASA leveraged its $800M COTS program budget [for both providers combined] with partner funds. This resulted in two new U.S. medium-class launch vehicles and two automated cargo spacecraft and demonstrated the efficiency of such partnerships."[3] A 2017 NASA Cost Analysis review was more direct: "the COTS development and later the operational Commercial Resupply Services (CRS) are significant advances in affordability by any measure."[4] Simply put, this approach works. That is why NASA is using a similar approach to the Power and Propulsion Element for Gateway.

Not only must NASA plan prudently to save money, it likely must also anticipate and plan for funding levels below its requests to Congress, due to budget issues entirely unrelated to the agency. Indeed, it appears that NASA is already anticipating and planning for such a scenario. When faced with budget shortfalls, NASA often attempts to make up for the shortfalls by: 1) cannibalizing one part of the agency to pay for another part of the agency; and 2) deferring, de-scoping, or discontinuing lower priority programs and activities within agency. Both options are demonstratively bad choices and lead to even worse results for the agency – undermining support for the Moon initiative, destabilizing other programs and missions, and leading to increased costs and schedule delays across the agency.[5] Rather than risks this all-but-guaranteed outcome, Congress should direct NASA to opt for a third option – public-private partnerships.

True commercial partnerships for development and operation of some elements of the exploration architecture represent the most rapid and cost-effective path to return to the Moon. Pay-for-performance creates the proper incentives on both sides of the Government/company relationship. Here, the GAO has reported: "[f]irm-fixed-price contracts place the onus on the contractor to provide the deliverable at the time, place, and price negotiated by the contractor and the government. In addition, firm-fixed-price contracts place the maximum risk on the contractor as well as full responsibility for all costs and any resulting profit or loss."[6]

It is now time for the United States to advance its national space exploration program. To do so, CSF recommends the following:

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[3] NASA, "Commercial Orbital Transportation Services: A New Era in Spaceflight," February 2014. Available at: https://www.nasa.gov/sites/default/files/files/SP-2014-617.pdf

[4] Zapata, Edgar. An Assessment of Cost Improvements in the NASA COTS/CRS Program and Implications for Future NASA Missions. American Institute of Aeronautics and Astronautics, 23 Oct. 2017, https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170008895.pdf, pp. 1.

[5] NASA Office of Inspector General, "NASA Cost and Schedule Overruns: Acquisitions and Program Management Challenges", June 2018. Available at: https://oig.nasa.gov/docs/CT-18-002.pdf

[6] Government Accountability Office, "NASA: Acquisition Approach for Commercial Crew Transportation Includes Good Practices, but Faces Significant Challenges," December 2011, (GAO-12-282). Available at: http://www.gao.gov/assets/590/587021.pdf.

1. **Use flexible development agreements like SAAs** for development activities and firm, fixed-price contracts for services;
2. **Focus procurement approaches and requirements on an outcome-oriented integrated commercial service** rather than a government owned or operated systems;
3. **Use competitively awarded, firm, fixed-price contracts** with payment for meaningful deliverables and milestones, not just for effort;
4. **Maintain competition throughout programs.** Two or more companies should proceed through the flight demonstration phase for each program element and into follow-on service phase;
5. **Eliminate Cost Accounting Standards (CAS) when there is competition and fixed price contracting.** CAS degrades speed and adds costs without improving contract performance. Fixed-price milestone contracts place risk on the contractor for costs and schedule, obviating the need for cost reporting elements. Cost Accounting Standards also serves as a barrier to entry for non-traditional firms, artificially limiting the competitive pool; and
6. **Mirror commercial terms and conditions to the maximum extent.** Eliminate all other FAR-derived provisions that are not essential to incentivizing the core outcome.

V. Support a smooth LEO industrialization and commercialization process that grows the LEO market

As this Subcommittee looks to how best ensure the country's ongoing leadership in space, it must carefully review commercial LEO efforts to ensure responsible use of finite taxpayer dollars and to encourage, rather than hamper, rapid innovation.

Last month, NASA released guidance for its Low Earth Orbit Economy initiative. These plans and policies include pricing for facilities and resources that may be accessed on a reimbursable basis by commercial entities onboard the ISS; an announcement of opportunity and associated costs to fly private astronauts; calling for proposals on opportunities to stimulate demand, a commercial use policy for the ISS, and other initiatives. CSF commends Administrator Jim Bridenstine and the entire NASA team for recognizing the success of the commercial industry, incorporating best practices learned from the agency's years of partnership with private companies, and updating its strategic objectives to accelerate additional development of these important capabilities.

As NASA works to implement its Low Earth Orbit Economy initiative and expand human presence in space, CSF recommends the following:

- Encourage NASA to adopt the best elements of its successful efforts to commercialize space, such as the Commercial Orbital Transportation Services (COTS) program and the Commercial Crew program. Whereas traditional cost-plus contracts can perversely incentivize companies to run over budget and behind schedule, NASA properly structured its commercial partnerships to develop new space capabilities at a rapid pace by implementing milestone-based agreements for development and firm-fixed-price contracting for services.
    - The COTS Program to develop uncrewed cargo resupply capabilities has been a clear success for NASA. A 2017 NASA Cost Analysis review of the program

was direct in its assessment of the benefits of true public-private partnerships: "the COTS development and later the operational Commercial Resupply Services (CRS) are significant advances in affordability by any measure."[7]

  - NASA's Aerospace Safety Advisory Panel (ASAP), the most conservative and safety-focused group within the agency, identified the commercial, competitive structure used under the Commercial Crew program as a preferred model for NASA's future development activities for human spaceflight systems, particularly in NASA's return to the Moon.[8]

- Maintain competition throughout a program's life, instead of just during the bidding process, to encourage ongoing innovation and cost-reduction. Multiple operational providers also offer redundant capabilities to assure NASA's access to space in the event of delays or technical challenges with one system.
- Support the full and complete utilization of the ISS through at least 2028, and a timely, seamless transition process towards commercial space stations to ensure that the United States maintains a continuous crewed presence in LEO. Continued industrial research and development activities on the ISS in the immediate term will identify new markets or new applications in space and inform future platform development.
- One of the most important things that the Government can do for the LEO economy is to provide certainty and predictability in the LEO marketplace by developing and communicating a clear plan for the transition to commercial systems. It also means that if NASA is going to charge for ISS-related services, those prices should change infrequently and with substantial advance notice. Above all, NASA must resist the temptation to try to make money now, at the expense of future LEO market expansion: this would be the very definition of "killing the goose that lays the golden eggs." The ISS was created for non-economic reasons, and it should not now have to be justified entirely on its near-term economic value.
- Regularly engage with industry to understand and continually incorporate new commercial capabilities as they evolve, as opposed to requesting that business fit into solely within NASA's plans.
- Support uses of the ISS that are based on scalable business models, and then support the scale-up of those models with consistent and plentiful access to upmass, operations, and downmass.
- Invest in "proof of potential" payloads and business models to identify potential markets for LEO commercialization.
- Grant users complete control over intellectual property developed on the ISS.
- Avoid competition with private industry. Simply put, the domestic commercial industry will not mature if the world's largest and best funded space agency is competing with it. As a key example, NASA should not provide "free" space transportation to countries that are not already participants in the ISS program. These countries would otherwise commercially procure seats to space for their astronauts on American suborbital and orbital spaceflight systems.
- Support the increased use of ISS as a destination for private astronauts, as well as support for new commercial LEO platforms.
- Stress the importance of short-duration, "sortie" missions to the ISS. These missions, lasting one to two weeks in length, offer NASA the opportunity to conduct more frequent

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[7] Zapata, Edgar. An Assessment of Cost Improvements in the NASA COTS/CRS Program and Implications for Future NASA Missions. American Institute of Aeronautics and Astronautics, 23 Oct. 2017, https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170008895.pdf, pp. 1.

[8] https://spacenews.com/safety-panel-calls-on-nasa-to-apply-commercial-crew-lessons-for-artemis/.

missions to space, promising greater scientific discovery and more opportunities for the astronaut corps to go to space than the current six month rotation missions allow. To reduce costs to the taxpayer, NASA should purchase seats on commercial missions to ISS to allow for a mixed NASA / commercial crew on these missions. Not only would this mission architecture better support NASA's objectives, it would also support the development of a marketplace for private passenger transportation to space.

- Establish a national microgravity policy initiative, informed by a Microgravity Decadal Survey. Microgravity research will stimulate the next technological and economic changes for the United States. As policy has recognized the importance of investment in artificial intelligence, similar policy needs to be established should foster the pursuit of innovation, technology development, and discovery where public.
- Microgravity Decadal Survey – microgravity research and development is critical to American leadership, discovery, exploration, and the development of the space economy. NASA, the National Science Foundation (NSF), and the National Institute of Health (NIH), should jointly fund the National Academies of Sciences, Engineering, and Medicine to carry out a microgravity decadal survey.
- Enhance utilization of the Flight Opportunities Program (FOP) for suborbital microgravity research. The Flight Opportunities Program enables low-cost access to environments where cutting edge research and development can be conducted. The Flight Opportunities Program is a key component of a microgravity R&D pipeline that contributes to the development of a robust low Earth orbit ecosystem. This pipeline can be strengthened by broadening the Flight Opportunities Program user community to include universities and academia, by allowing basic and applied science payloads to fly in addition to technology development payloads, and by enabling principal investigators (PIs) to fly alongside and tend to their payloads during flight.
- Assume a long-term view of LEO commercialization and avoid "taxing" early commercial efforts as a means to fund ISS operations or deep space in the short term.

VI. Conclusion

These are exciting times in spaceflight. We should all be proud of what the American space enterprise—both the Government and the private sector—is achieving. The challenges we face to achieve our goals today are not small, but we have the ability and opportunity to address them in a thoughtful and impactful manner given Congress' and the Administration's support.

We are ready to take the next steps to expand America's commercial sphere of influence from the edge of space, to the Moon, Mars, and beyond, and we look forward to continuing to work together to advance the United States' leadership in space. Chairwoman Horn, Ranking Member Babin, I appreciate your invitation to testify before the Subcommittee today. Thank you for your attention, and I look forward to your questions.

Eric W. Stallmer

Eric Stallmer is the President of the Commercial Spaceflight Federation. CSF is the largest trade organization dedicated to promoting the development of commercial spaceflight, pursuing ever-higher levels of safety and sharing best practices and expertise throughout the industry. Under Stallmer's leadership, CSF has worked tirelessly to craft the modern Commercial Space Launch Act, as well as to promote innovation as a national policy to spur the economy and create high technology jobs. In addition, CSF works to develop industry standards and encourages further growth in the commercial spaceflight industry.

Stallmer has been recently appointed to the National Space Council Users' Advisory Group (UAG), where he has provided testimony at the 2nd National Space Council meeting. He serves as co-chair of the Federal Aviation Administration (FAA) Airspace Integration Aviation Rulemaking Committee (ARC) and is a member of the Space Launch and Reentry ARC and the Spaceport ARC. Stallmer is also a member of the FAA's Commercial Space Transportation Advisory Committee (COMSTAC).

Stallmer constantly promotes the industry and CSF member companies through his outreach to high-ranking government officials and high-profile media outlets. His professional comments have been featured in The Washington Post, Wall Street Journal, Bloomberg, NBC Today Show, ABC News, CBS News Radio, Fox News, The BBC, CNBC, SpaceNews and many more. Stallmer also promotes the mission of CSF through participation at multiple industry conferences throughout the year.

Stallmer has testified before both the House Committee on Science, Space, and Technology as well as the Senate Commerce committee. He recently testified at a hearing titled, "The Commercial Space Launch Industry: Small Satellite

Opportunities and Challenges." There he encouraged Congress to support policies that will facilitate growth and innovation in the industry, and maintain the American space sector's competitive leadership. He has served on numerous industry affiliated boards including
the Future Space Leaders Foundation and is the former Chairman of the Washington Space Business Roundtable.

Before working at CSF, Stallmer served as the Vice President of Government Relations at Analytical Graphics Inc. (AGI). Stallmer joined AGI in 2002. While there, Stallmer oversaw all Washington Operations and represented AGI's commercial off-the-shelf products and technology to defense, intelligence, Congress and civil government sectors within the aerospace industry.

Stallmer came to AGI from The Space Transportation Association (STA), a non-profit, industry trade organization providing government representation to companies with a vested interest in the U.S space launch industry. Prior to that, Stallmer worked on Capitol Hill in the office of then Congressman Tom Coburn.

For more than two and half decades, Stallmer has served as an Officer in the United States Army and Army Reserves. He was awarded the Bronze Star Medal for meritorious service while engaged in combat operations during Operation Iraqi Freedom. He has served as an Adjunct Professor of Military Science at Georgetown University and is currently assigned to the Pentagon in the Office of the Deputy Chief of Staff Army for Logistics, G-4.

Stallmer earned a Master of Arts Degree in Public Administration from George Mason University and a Bachelor of Arts Degree in Political Science and History from Mount Saint Mary College. He and his wife Amy live in McLean, Virginia with their three children, Charlie, Billy and Catherine.

Chairwoman HORN. Thank you, Mr. Stallmer. Mr. French?

TESTIMONY OF MIKE FRENCH,
VICE PRESIDENT, SPACE SYSTEMS,
AEROSPACE INDUSTRIES ASSOCIATION

Mr. FRENCH. Chairwoman Horn, Ranking Member Babin, and distinguished Members of the Subcommittee, thank you for the opportunity to testify today. The Aerospace Industries Association (AIA) represents nearly 340 companies at the heart of the American economy. The aerospace industry generates nearly $930 billion in economic output, and nearly $90 billion in trade surplus, the largest of any U.S. sector. Our industry is supported by more than 2.5 million American workers, and our members have partnered with NASA since its beginning. But today our eyes are firmly fixed on the future. This year AIA released a report entitled, "What's Next for Aerospace and Defense: A Vision for 2050." This report paints a picture of the innovations that will drive the way we move, connect, explore, and defend our interests 30 years from now, and many of these technologies will depend on an effective partnership between government and the commercial space industry.

As Dr. Lal said, there's been much discussion about commercial space, but the term is often inconsistently applied. The commercial space industry is not a new phenomenon. It is part of a $360 billion economy that's existed for decades. Commercial space companies range from established, publicly traded companies, to large private companies, to startups that are still developing their business plans. For example, NASA's commercial crew and cargo partners are the Boeing Corporation, Northrup Grumman, Sierra Nevada Corporation, and SpaceX. In an important trend, these large public space companies are now among the most active venture capital investors in space startups.

In deciding how to partner with this diverse set of actors, government has a variety of different tools and approaches it can use, depending on where the market is. For example, NASA took a new approach in the commercial cargo and crew programs, creating what I'll call a public investment, private service, or PIPS model. Under PIPS, NASA subsidized the creation of commercial service by being the primary customer, while requiring investment from its commercial partners. NASA determined the PIPS model was viable for commercial cargo and crew because of the existence of the multibillion-dollar commercial launch industry.

Over the last few weeks, NASA announced its intent to use the PIPS model for the Artemis Program's human lunar lander. This is a new extension of the model, and it presents three primary risks that I wanted to raise with you today. First, there's no established market offering for this—for NASA to buy here. The capability of landing humans on the Moon will require a great deal of development before it can be provided to NASA as a service. Second, requiring companies to invest internal funds in a nascent market may prevent firms that otherwise are highly capable, especially small and mid-sized firms, from being able to compete. Third, purchasing services will require a clear outline of government versus industry responsibilities, as was required in the cargo and crew

programs, but this would be more complex, as this will take place within an entirely new program operating deeper in space. These risks will require NASA to make a robust assessment of where the proposals it receives meet technical and schedule requirements, and limit default. It also requires NASA to clearly delineate these government/industry responsibilities, which may require NASA to change its approach in some areas. We urge NASA to consider industry's feedback to help mitigate these risks as it proceeds.

Moving forward, Congress can provide direction on these approaches as it considers NASA's next authorization and appropriation bills. Of course, Congress' actions are not limited to procurement policy. One essential component to commercial growth worth noting is reliable, interference-free spectrum. A viable commercial space landscape requires a comprehensive approach to our Nation's future spectrum policy that ensures adequate and globally harmonized spectrum. As government looks to meet its future space requirements, Congress should continue to be an active ally to commercial space, whether through passing a multi-year NASA authorization, ensuring we have the most talented workforce, or deciding the best procurement strategies. Regardless, the commercial space industry is primed to partner with government and meet the next set of space challenges, from the continued support of U.S. national security space to returning to the Moon, and on to Mars. I thank you very much.

[The prepared statement of Mr. French follows:]

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BY WITNESS
July 25, 2019

Testimony of Mike French
Vice President, Space Systems
Aerospace Industries Association

before the

Subcommittee on Space and Aeronautics
Committee on Science, Space, and Technology
U.S. House of Representatives

Chairwoman Horn, Ranking Member Babin, and distinguished members of the Subcommittee, thank you for the opportunity to provide testimony today on the commercial space sector.

The Aerospace Industries Association (AIA) represents an aerospace and defense (A&D) industry that is at the heart of the American economy, generating $929 billion in economic output and a trade surplus of nearly $90 billion in 2018 – the largest of any U.S. exporting sector. Our industry is supported by more than 2.5 million dedicated employees – representing 20 percent of the nation's manufacturing workforce – who are responsible for the continuous stream of innovations that improve American lives.

Moreover, our members helped create the foundation of America's space efforts, starting with the Mercury Program. They enabled NASA's exploration of our solar system, put the first humans on the Moon, and supported countless missions since. We are proud that our innovations have shaped history and have been particularly gratified to recognize these contributions as the world celebrates the 50th anniversary of Apollo 11. But our eyes are also focused firmly on the future.

Earlier this year, AIA released a report called "What's Next for Aerospace and Defense: A Vision for 2050." Based on in-depth interviews with Chief Technology and Chief Strategy Officers across the industry, the report paints a picture of the innovations that will drive the way we move, connect, explore, and defend our interests thirty years from now. And it should not surprise you to know that many of these technologies rely on space and will depend on an effective partnership between government and the commercial space industry.

Our companies, of course, are not waiting for 2050. They are living these partnerships every day. Northrop Grumman Corporation's Antares and Cygnus and Sierra Nevada Corporation's Dream Chaser are partnered with NASA to resupply the International Space Station (ISS).

Virgin Galactic's SpaceShipTwo will soon transport passengers to space, while The Boeing Company's Starliner will soon launch U.S. astronauts to the International Space Station from U.S. soil. They set the stage for taking the next Americans to the Moon and beyond on Boeing's Space Launch System and Lockheed Martin Corporation's Orion spacecraft. These examples are only a glimpse into the role of commercial space companies – from small to midsize to large – in ensuring America's space leadership.

Long-standing Government and Commercial Space Link

The commercial space industry is not a new phenomenon. It is part of a $360 billion space economy that has existed for decades.[1] It supports commercial activities, like satellite communications, and has supported government space activities since the beginning of the space age. Just look to the Apollo 11 landing, a historic moment made possible by the contribution of more than 370,000 contractors from industry and academia. The Space Shuttle, International Space Station, NASA's missions to explore our solar system, and now NASA's commercial cargo and crew programs are all connected to the contributions and leadership of commercial space companies.

In recent years, there has been much discussion about "commercial space," but that discussion has lacked consistency on what constitutes "commercial." The definition of commercial is often inconsistently applied across companies, programs, and contracting mechanisms. While a common perception is that commercial space companies are small start-ups with private financing, government's commercial space partners have, in fact, spanned a range of corporate types – including established, publicly traded companies; recent startups funded by private capital; and private firms supported by both private and public investment.

There is not just one model for a commercial space business. NASA's high-profile commercial cargo and crew programs provide a perfect example, as the primary partners are companies with diverse portfolios that include significant government contracting activity from three publicly traded companies and one private company.

While commercial space has existed for decades, in recent years, several hundred private investment-backed firms have entered the sector. These firms are not monolithic, and how they fit within the existing commercial space economy is important to understanding their role in current and future government space activities.

These newer companies fall into two general categories. The first is a handful of more fully-capitalized companies actively engaged as direct government contractors or suppliers. The second and much larger group of these companies remain in a pre-revenue phase and are still developing their planned space offerings.

[1] Bryce Space and Technology, 2018 Global Space Economy

This latter group of companies is more likely to be active in "data-buy" programs (e.g., NASA and NOAA's purchase of commercial remote sensing data), the government's early stage funding programs (e.g., the Small Business Innovation Research and the Small Business Technology Transfer), and more recent programs intended to engage with these types of firms, such as NASA's Jet Propulsion Laboratory's space accelerator.

In addition to private funding, many of these newer firms have also received significant government investments. A recent report found that, of the companies that received private capital from 2000 to 2018, they also received $7.2 billion in U.S. public funding during this period.[2] Of firms that received both private and public funding, cumulative total investment from both public and private funding areas was about equal.[3]

Overall, the commercial space industry is one that is diverse, including small and large companies and companies that receive private and public investment, and has been growing. This presents both new opportunities and risks for the government as it continues to look to the commercial sector to meet its requirements.

Shifting Procurements Strategies

The government has a series of tools available to meet these requirements in the space arena. In NASA's case, these tools include:

- Off-the-Shelf / Low-Dollar Items: simplified acquisition methods run by the Government Services Administration, other agencies, or NASA itself;
- Federal Acquisition Regulation (FAR): fixed-price and cost-plus contracts to both buy services and develop new capabilities; and,
- Space Act Agreements: a statutorily provided transaction authority that allows NASA to partner with industry in an either cost reimbursable, no exchange of funds, or funded arrangement.[4]

In deciding which of these frameworks to use, the government typically considers the requirements it needs from a product or service and what the commercial market currently provides. In the case of a widely available commercial product, like printer paper for example, the government is well served to buy the off-the-shelf product.

[2] U.S. Government Support of the Entrepreneurial Space Age, Space Angels, 2019
[3] U.S. Government Support of the Entrepreneurial Space Age, Space Angels, 2019
[4] NASA has limited its use of funded Space Act Agreements when it determines it is acquiring a good or service. In that case, NASA will use the FAR.

Conversely, as the government seeks to build a next generation stealth bomber, meeting its requirements will involve significant new developments that are not commercially available. The government will also desire a significant level of control in both the development and ultimate use of a stealth bomber, given its function and capabilities. In this case, the government would be best served to use a cost-plus FAR framework.

In some cases, the market may have an available product, but the government may also desire a level of control or enhanced capabilities that cannot be met commercially. Satellite communications are a market example of where the government takes multiple approaches. The government procures commercially available satellite bandwidth for its use from satellites operated by companies (essentially, buying an off-the-shelf service). The government also contracts with commercial space companies in a fixed-price or cost-plus model to build specialized communications satellites the government itself will use and control.

In the space context, the government has shifted its procurement strategies in some areas based on an assessment of where the commercial space industry's capabilities and market fall along the printer paper to stealth fighter spectrum. This is most visibly seen in NASA's commercial cargo and crew programs. In these programs, NASA used a "public investment/private service" model, which is when government subsidizes the creation of a commercial service as the primary customer, while also requiring companies to invest varying levels of private funds into the development of that service.

Under this model, NASA funded the majority of the development of new launch vehicles and spacecraft by purchasing the future "service" of companies transporting NASA cargo and astronauts to the International Space Station. The prime companies in these two programs are The Boeing Company, Northrop Grumman Corporation, Sierra Nevada Corporation, and SpaceX.

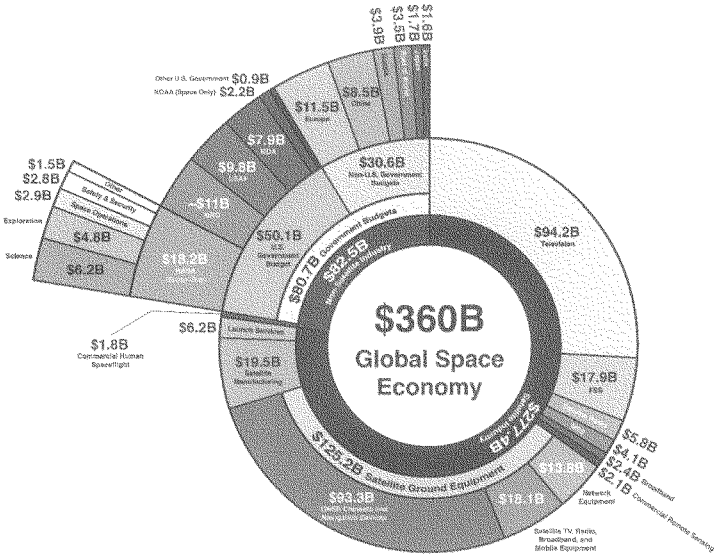
This is in contrast to a model where NASA would fund the development of a launch vehicle or spacecraft that NASA *itself* would operate to transport cargo and astronauts. Further, NASA crafted the procurement to require industry to commit some level of internal investment to the effort. This was again based on an assessment of the market and a determination that industry would be willing to make this commitment based on the opportunity to gain commercial business from the ensuing capabilities.

Market Maturity Important to Procurement Choices

NASA recently announced its intent to use this newer "public investment/private service" model for the procurement of a human lunar lander for the Artemis Program.
The extension of the public investment/private service model to new areas requires a nuanced understanding of the commercial space market today and a realistic assessment of its direction to ensure overall risks and opportunities are being considered.

A partnership in an area with a robust, competitive market will allow different opportunities and risk postures than partnerships in areas that are considered nascent markets.

2018 Global Space Economy



Source: Bryce Space and Technology

According to 2018 data, satellite services are a leading driver of the space economy, with significant economic activity also occurring in satellite manufacturing, ground systems, and launch services (see 2018 Global Space Economy graph).

The existence of a multi-billion-dollar commercial satellite launch market was critical to NASA's procurement decision regarding the commercial cargo and crew programs. Given the existence of this market, NASA weighed the present capabilities of U.S. industry with the status of the market and determined this was an area where the "public investment/private service" model procurement strategy was viable.

At the time, NASA understood this presented a risk. Although the market was established and launch solutions existed, NASA would not be buying an "off-the-shelf" capability. Launch vehicles and spacecraft would still have to be developed by industry to provide the procured services. Further, NASA assessed industry would be willing to put in some level of internal investment, with the rationale that the ensuing launch vehicles could be used by the companies to gain commercial business apart from NASA.

As NASA considers using the "public investment/private service" procurement model more widely, it is important to assess the market in emerging areas and whether they are presently or expected to be revenue generating. From a NASA procurement perspective, using a "public investment/private service" model framework creates a different risk posture if used in areas that lack a current or near future market.

Looking at the global space economy, there is not an active commercial lunar market. The lack of a current market in deep space activity presents three primary risks in using a "public investment/private service" model procurement strategy.

First, given there is no current commercial market in deep space, there are not established commercial services for NASA to buy today. Therefore, the service of landing humans on the Moon will require a great deal of development before it can be provided to NASA. These services today are far from "off the shelf"

Second, requiring commercial companies to invest internal funds in an area with limited market prospects may prevent firms that are otherwise highly capable from competing to provide the service. As the future market is more speculative, the risk of investment and the potential time to see a return increases. Depending on the level of required investment by NASA, this could especially impact medium and smaller companies that are unable to take these risks, even if they have leading capabilities.

Third, purchasing these capabilities as services will require a detailed assessment and clear, predefined determination of government versus industry responsibilities to ensure the overall program is integrated successfully. Determining these responsibilities required significant cooperation between government and industry in the commercial cargo and crew programs, and there is the risk this will be increasingly complex in a deep space program.

From NASA's perspective, these risks will require the agency to make a robust assessment of whether the technical, schedule, and price proposed by industry will close present capability gaps to meet NASA's technical and schedule requirements. Further, NASA will have to consider whether any proposed industry investment is supported by a realistic assessment of future business. Having reviewed the market and considered these factors, there may be areas where NASA determines a different procurement path is necessary.

Finally, no matter the procurement model, NASA will require clear human safety requirements as well as a level of insight, oversight, and transparency into the development of human-rated systems. Currently, it will be NASA astronauts flying on these systems and the government serving as primary funder and customer. To the extent the "public investment/private service" model is extended to lunar activity, NASA is likely to be held responsible for safety at the end of the day. In this regard, Congress can learn from what worked well and where NASA ran into roadblocks during the commercial crew development process.

Congress as a Space Ally

Congress' review of the commercial space landscape and its policy decisions will shape both government action and the commercial space market.

As you consider NASA's next authorization and appropriations bills, Congress should provide direction about the motivation and objectives of our deep space exploration investments and the role of NASA and its commercial partners in these arrangements. In some cases, Congress may find a set of space activities are core national capabilities, similar to assets owned and operated by the Department of Defense, while in others, it may find industry-ownership and control beneficial.

Of course, Congress' actions are not limited to procurement policy, but have impacts across the space policy domain. An often forgotten and essential component to commercial space growth is the need for reliable, interference free, radio frequency spectrum for everything from launch and re-entry to accurate, timely, and reliable weather forecasting data. Spectrum is space's invisible nervous system, allowing critical data to be transmitted to and from Earth. Without access to this spectrum, our nation's space assets and capabilities cannot communicate. Building a viable commercial space landscape requires a comprehensive approach to our nation's future spectrum policy that ensures adequate and globally-harmonized spectrum for a full range of space uses: commercial, civil, and national security.

These are just a few examples of the many roles – from passing a multi-year NASA reauthorization to investing investment in STEM education and ensuring we have the most talented workforce – where Congress should be an active ally in ensuring a thriving space enterprise.

The commercial space industry has been a partner with government since the earliest days of the U.S. space program and will continue to be while government looks to meet its future space requirements and consider various procurement models. Whatever approach the government chooses, commercial industry is primed to meet the next set of space challenges, from the continued support of U.S. national security to returning to the Moon and going beyond.

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MIKE FRENCH
Vice President, Space Systems
Aerospace Industries Association

Mike French is Vice President for Space Systems at the Aerospace Industries Association. As the lead of the Space Systems policy division, Mike works with AIA's membership to advocate for policies, regulations, and investments that ensure American leadership and strong industry partnership across the civil, commercial, and national security sectors.

Mike's experience in the space industry ranges from advising senior government leaders on space policy, to developing market forecasts and assessments for industry executives, to analyzing major space investments for companies and banks. He previously served as the Senior Vice President for Commercial Space at Bryce Space and Technology, a market analysis and management consulting firm. At Bryce, he advised major aerospace industry clients on management, policy, and investment decisions.

Mike has also held several federal government positions, most recently serving as NASA's Chief of Staff, advising the NASA Administrator, White House, and other government leadership on national space policy issues. He received NASA's Distinguished Service Medal for his service. Prior to serving in government, he practiced law in the defense and aerospace sector in Los Angeles where he advised clients on matters regarding aircraft and aerospace weapons systems.

Mike holds a Bachelor of Science in business administration from the Haas School of Business at the University of California, Berkeley and a J.D. from Harvard Law School.

1000 Wilson Boulevard, Suite 1700
Arlington, VA 22209-3928
703.358.1000

Chairwoman HORN. Thank you, Mr. French. Ms. Montgomery?

TESTIMONY OF LAURA MONTGOMERY, PROPRIETOR, GROUND BASED SPACE MATTERS, AND PROFESSOR, CATHOLIC UNIVERSITY'S COLUMBUS SCHOOL OF LAW

Ms. MONTGOMERY. Thank you. Chairwoman Horn, Ranking Member Babin, and distinguished Members of the Subcommittee, thank you for inviting me to participate today. Three regulatory agencies oversee U.S. commercial space activities. The FAA authorizes and regulates commercial space transportation, launch, and reentry, but does not have authority on orbit. The FCC oversees communication satellites, and NOAA regulates remote sensing satellites. In response to Administration calls for streamlining, the three agencies have issued Notices of Proposed Rulemaking to fix their regulations. They have made good attempts, but the FAA and FCC have also taken the opportunity to impose new regulations, not all of which are clearly within the authority granted to them by Congress.

The FAA, for one, proposes to ask payload operators, whom Congress neither told it to license nor regulate, whether they encrypt their transmissions. But is this request for information actually a disguised requirement? Although Congress has given the FAA some authority over payloads, in that the FAA may stop a launch for payload concerns, Congress has otherwise been clear that it has not provided the FAA the authority to regulate payloads.

The FCC also issued an NPRM to modify its orbital debris regulations. In stark contrast to Congress' financial risk approach for space transportation, the FCC proposes that satellite operators indemnify the U.S. Government against damage claims. If Congress has not said that the satellite industry must protect the U.S. Government, one might ask, first, how the FCC thinks it has the authority to do so, and second, why it has chosen a different path for a related space industry? Because it is the legislative branch, Congress has the ability to choose a different path for satellites. The FCC does not.

There are three controversial provisions of the Outer Space Treaty that Congress could interpret in favor of incentivizing private commerce. It is my own view that interpretations that incentivize are the right ones. The first involves the regulation of private entities in space. Article 6 of the treaty says that the activities of nongovernmental entities in outer space shall require authorization and continuing supervision by the appropriate state party. The FAA has indicated that it may deny a private entity access to space if the private entity's activities are not federally regulated.

This part of the treaty is not, however, self-executing, which means that it does not create an obligation on the private sector until Congress says so by passing legislation. The treaty does not say that either all or any particular activity must be authorized, which leaves decisions regarding what activities require regulation to the member states. And, in the United States, those decisions are up to Congress, not the FAA. The FAA's position ignores the Supreme Court in Medellin vs. Texas, where the Court held that not even the president could enforce a non-self-executing treaty.

The FAA should thus not claim the power to use the treaty to deny a non-governmental entity access to space.

Next come property rights. The treaty bars national appropriation in outer space. This creates legal uncertainty for the private sector. For U.S. companies, Congress resolved half the uncertainty by recognizing private claims to extracted resources back in 2015. Property rights in land are less certain. Many interpret the Outer Space Treaties as barriers to private property under different theories. A careful reading, however, shows that contrary theories may better reflect what the treaties actually say.

Finally, the Outer Space Treaty admonishes states parties to avoid harmful contamination of outer space. There are two questions at issue here. First, does the admonition apply to non-governmental entities? Does the treaty—and second, does the treaty's harmful contamination mean the same thing as NASA's planetary protection policy, under which spacecraft undergo expensive sterilization procedures? First, the treaty limits this requirement, like many others, to States' parties to governments and their emissions. When the drafters of the treaty intended a requirement to not—apply to non-governmental entities, they said so. Here they did not. Next, although the treaty warns against harmful contamination, NASA's planetary protection policy would avoid almost all contamination in order to preserve its ability to study other worlds in their natural states. NASA thus not only avoids what the ordinary person might consider harmful, but microbial contamination as well. NASA is being a good science steward, but it is a NASA policy, and not the law.

Thank you for the opportunity to contribute today.

[The prepared statement of Ms. Montgomery follows:]

Testimony of Laura Montgomery
Before the Committee on Science, Space, and Technology
Subcommittee on Space
The Commercial Space Landscape: Innovation, Market, and Policy
July 25, 2019
2318 Rayburn House Office Building

Chairwoman Horn, Ranking Member Babin, and Members of the Subcommittee, thank you for inviting me to participate in your discussions of the issues surrounding commercial space activity.

In my testimony, I will address the regulatory landscape, how to tell whether a launch or reentry needs a license or is a government activity, concerns with Federal Aviation Administration (FAA) and Federal Communications Commissions (FCC) forays into regulating matters outside their jurisdiction, and three contentious issues under the Outer Space Treaty. I will close with an analysis of how we may interpret the Outer Space Treaty so as not to unduly burden the private sector.

I. **The regulatory landscape**. As you are aware there are three regulatory agencies that oversee U.S. commercial space activities. Under authority delegated from the Secretary of Transportation, the FAA authorizes and regulates two legs of commercial space transportation, namely, launch and reentry to ensure they do not jeopardize the public health and safety, safety of property, or national security or foreign policy interests of the United States.[i] It also imposes financial responsibility requirements, usually in the form of insurance, and administers reciprocal waivers of claims among launch and reentry participants, including space tourists and other space flight participants. The FCC licenses and regulates communications satellites in outer space.[ii] Lastly, a commercial entity operating a remote sensing system in space must obtain a license to do so from the Secretary of Commerce's[iii] National Oceanic and Atmospheric Administration (NOAA).

In the transportation context, the Commercial Space Launch Act makes clear when a launch or reentry is commercial: unless the launch or reentry is carried out by the U.S. Government and the activity is for the U.S. Government, the launch or reentry by a U.S. entity or anyone within the United States requires an FAA license, and is thus characterized as "commercial."[iv]

All three agencies impose regulatory requirements on commercial operators, with varying degrees of burden on the private sector. In response to industry concerns, the President's National Space Policy Directive-2[v] (SPD-2) set a new direction for the FAA and NOAA. In SPD-2 the President directed the agencies to align their regulations with his goals, including ensuring that "regulations adopted and enforced by the executive branch promote economic growth; minimize uncertainty for taxpayers, investors, and private industry; protect national security, public-safety, and foreign policy interests; and encourage American leadership in space commerce."[vi]

Since then, the FAA, the FCC, and NOAA have all issued notices of proposed rulemaking to amend their regulations. They have all made good attempts to alleviate unnecessary regulatory burdens, but the FAA and the FCC have also taken advantage of the opportunity of a rulemaking to impose additional regulations, not all of which are clearly within the authority granted to them by Congress.

A. The FAA.

1. "Information" required of payload operators. Congress explicitly assigned the FAA authority to authorize and regulate the launch of launch vehicles, the reentry of reentry vehicles, and the operation of launch and reentry sites. Congress did not give the FAA authority to regulate activities on orbit, or the payloads of a launch or reentry vehicle. However, Congress did give the FAA the authority to prevent the launch or reentry of a payload if no other agency authorized it and if the FAA decided the launch or reentry would jeopardize the public health and safety, safety of property, or national security or foreign policy interest of the United States.[vii] Nonetheless, the FAA proposes to require information about encryption for satellites on orbit, raising the question of whether this request for information is actually a disguised requirement and whether the FAA has exceeded the authority Congress granted it.

The FAA is walking a very fine line with its proposed request. The agency wouldn't technically require a satellite operator to employ encryption. It would merely *inquire* whether it does. The FAA proposes that a payload operator describe:

> any encryption associated with data storage on the payload and transmissions to or from the payload. Encryption helps ensure against cyber intrusion, loss of spacecraft control, and potential debris-causing events. The FAA is proposing these additions to the information requirements for launches to assist other federal agencies because NASA and the Department of Defense [DOD] frequently have requested this information in response to the FAA's interagency review in order to determine whether the proposed payload would jeopardize the safety of government property in outer space, or U.S. national security.

2. The FAA's authority to stop a launch because of a payload. In the United States, the Constitution gives Congress, not the Executive Branch, the power to legislate, that is, the power to write laws. Congress may delegate that power (and has done so many times) to the Executive Branch, including to the FAA. Congress has given the FAA some authority over payloads. It's not much, but it's some. Under 51 USC 50904(c), Congress said that the FAA:

> shall establish whether all required licenses, authorizations, and permits required for a payload have been obtained. If no license, authorization, or permit is required, the Secretary may prevent the launch or reentry if the Secretary decides the launch or reentry would jeopardize

> the public health and safety, safety of property, or national security or foreign policy interest of the United States.

Congress delegated the FAA's authority to stop a launch because of a payload not otherwise licensed in 1984. Since then, however, Congress has been quite clear that it has not provided the FAA the authority to *regulate* payloads. When Congress granted the FAA the authority to regulate the reentry of reentry vehicles in 1997, the House Committee Report[viii] reminded the FAA that the agency was not to regulate activities on orbit:

> The original Act intended that a launch ends, as far as the launch vehicle's payload is concerned, once the launch vehicle places the payload in Earth orbit or in the planned trajectory in outer space. The Committee wishes to make clear that the Secretary [of Transportation and by delegations the FAA] has no authority to license or regulate activities that take place between the end of the launch phase and the beginning of the reentry phase, such as maneuvers between two Earth orbits or other non-reentry operations in Earth orbit; or after the end of a launch phase in the case of missions where the payload is not a re-entry vehicle.

This seems clear. Mostly, the Committee was intent on ensuring that the FAA did not regulate reentry vehicle activities on orbit. It made sure, however, to clarify that other payloads also fall outside the FAA's authority to license or regulate. Thus, the FAA's authority over a payload should be limited to its ability to stop it from being launched.

3. Implications of an "information" requirement. If the FAA may not regulate payload operations or other operations on orbit, what does it plan to do with the encryption information it wants to request? Does it plan to assess the adequacy of a payload operator's encryption? Would it stop a launch if a payload operator did not have encryption? What if another agency was concerned? The FAA cites rational policy reasons for wanting the information, but it must first have the authority to implement them. Just as the FAA may not decide to regulate the meat-packing industry because of rational, sound (but hypothetical) concerns over trichinosis that it fears the Department of Agriculture has failed to adequately address, so should the FAA not start down the road to subtly but effectively imposing requirements on payload operators over whom it does not have authority. Although couched as an information requirement, if the FAA uses a payload operator's lack of encryption to stop a launch, the FAA is effectively requiring the operator to employ encryption on orbit.

The genuine and sincere interest of these other agencies in the encryption information is not a grant of Congressional authority. Legislative authority does not come from NASA or the Department of Defense, but from Congress. If the FAA does not expect to do anything about the encryption information, then the proposed new burden appears to have no point. If the FAA would do something about a satellite operator's encryption plans, the FAA may be attempting to regulate on orbit.

The right way to do it. There is a more appropriate avenue for the other agencies to obtain this information. NASA and DOD could seek authority from Congress and have an open conversation about their needs with the Constitutionally designated lawmakers. They could ask Congress to amend the FAA's statute so that the FAA could ask for this information, and, perhaps, even do something about it. But that has not yet happened.

B. The FCC. The Federal Communications Commission also issued a notice of proposed rulemaking this year. In it the agency proposed to modify its 2004 orbital debris regulations. Under its current space debris mitigation regulations, the FCC requires satellite operators to disclose information regarding their operations, maintain their orbital locations , and, at the end of a satellite's life, dispose of it properly. Most of the FCC's proposed new requirements address these issues.

1. Jurisdiction over insurance requirements and indemnification. The FCC, without citing any authority from Congress and in contravention of Congress' own approach in a similar context, proposes that the satellite operators it licenses purchase insurance and indemnify the U.S. Government against damage claims under the Outer Space Treaty and the Liability Convention. The FCC's proposed requirements stand in stark contrast to the Commercial Space Launch Act, where a licensed launch or reentry operator may be eligible for indemnification from the U.S. Government. The FCC requirement, however, would require an operator to indemnify the government.

This is a questionable choice to make on the part of the FCC. Typically, allocation of financial risk involves the type of policy choices that are made by Congress, that is, the type of policy determinations that are legislative in nature. The Constitution vests legislative powers in Congress. Just as it is rational for Congress to decide to protect the launch industry to some extent from claims for damage so might it have chosen not to. Likewise with the satellite industry where Congress has not yet spoken.

If Congress has not said that the satellite industry must protect the U.S. Government, one might ask, first, how the FCC thinks it has the authority to do so, and, second, why it has chosen a different path for a related space industry? Because it is the legislative branch, Congress has the ability to choose a different path. The FCC does not.

2. Jurisdiction over orbital debris. Interestingly, the FCC also invited comments on its authority over orbital debris, asking whether it properly found authority for the requirements it promulgated in 2004, and for what it proposes now. The Commission said:

> The 2004 Orbital Debris Order specifically referenced the Commission's authority with respect to authorizing radio communications, including the statements in the Act that charge the FCC with encouraging ''the larger and more effective use of radio in the public interest,'' and provide for licensing of radio communications, upon a finding that the ''public convenience, interest, or necessity will be served thereby.'' Did the 2004 order cite all

> relevant and potential sources of Commission authority in this area? Do the provisions discussed, or other statutory provisions, provide the Commission with requisite legal authority to adopt the rules we propose today?

The FCC's claim to jurisdiction rests on a thin reed. According to the FCC in 2004, its jurisdiction over orbital debris rests merely on its conclusion that "orbital debris mitigation issues are a valid public interest consideration in the Commission's licensing process." Although the FCC has authority over "all interstate and foreign communication by . . . radio and all interstate and foreign transmission of energy by radio, which originates and/or is received within the United States," 47 U.S.C. 152(a), it is unclear how the FCC has interpreted this jurisdiction to extend to orbital debris, which is not radio communication.

If the FCC can regulate anything of public interest other than broadcast and transmissions, one wonders what it can't regulate? Debris generation is not radio communication.

II. The Outer Space Treaty's Opportunities.

There are three controversial provisions of the Outer Space Treaty where the three different branches of the U.S. Government could interpret ambiguities in favor of commercial operators to incentivize private commerce, exploration, science, and settlement. It is my own view that such interpretations are the right ones. They include Article II's prohibition on national appropriation of outer space, including[ix] the Moon and other celestial bodies,[x] Article VI's call for the authorization and continuing supervision of non-governmental entities in outer space,[xi] and Article IX's requirement that States Parties pursue their studies and exploration of outer space so as to avoid harmful contamination to outer space and adverse changes in Earth's environment resulting from the introduction of extraterrestrial matter[xii]. Advocates from academic and governmental institutions have argued that these provisions bar commercial ownership of property in outer space[xiii], require governmental authorization and supervision of all private activities in outer space[xiv] or prohibit private U.S. activity without that authorization and supervision[xv], and that the harmful contamination provisions apply to private actors. These interpretations are burdensome and unnecessary.

A. Authorization and continuing supervision. Article VI of the Outer Space Treaty says that, "The activities of non-governmental entities in outer space, … shall require authorization and continuing supervision by the appropriate State Party to the Treaty." Article VI does not say that either all or any particular activity must be authorized, which leaves decisions regarding what activities require regulation to the member states. Article VI is not, under U.S. law, self-executing, which means that it does not create an obligation or a prohibition on the private sector unless and until Congress says it does. In other words, the regulatory agencies of the Executive Branch may not rely on Article VI to bar private access to space.[xvi]

Article VI says neither that *all* or *any particular activity* shall require authorization and continuing supervision. One country might, for example, impose price controls on platinum group minerals returned to Earth from an asteroid. Another might not. Article VI grants the States Parties to the treaty the same latitude in deciding what activities require authorization and continuing supervision. Asteroid mining itself might require no regulation because it would harm no one. In contrast to mining on Earth, where safety and environmental concerns provide a need for independent oversight, robotic mining of rocks in space far from any human habitation may not require regulation because no one lives on the rock, it has no visitors, and no one will get hurt by it.

One administration interpreted Article VI to require the authorization of any and all non-governmental activities in outer space.[xvii] Additionally, the Federal Aviation Administration has indicated that it may deny a private entity access to space because of Article VI.[xviii]

The FAA's position ignores Supreme Court law regarding non-self-executing treaties. Although the Constitution describes treaties as the supreme law of the land, they must be self-executing in order to be enforceable federal law without implementing legislation from Congress. As the Supreme Court has noted, "not all international law obligations automatically constitute binding federal law enforceable in United States courts."[xix] In the case of *Medellin v Texas*, the Supreme Court held that not even the President could execute a non-self-executing treaty provision.[xx] Regulatory agencies such as the FAA should thus not claim the power to use Article VI, which is non-self-executing, to deny a non-governmental entity access to space.

B. Private conformity with the treaty. Some claim that Article VI's provision that States Parties to the treaty assure "that national activities are carried out in conformity with the provisions set forth in the present Treaty" means that commercial actors must abide today, even absent legislation, by each provision in the treaty, even the provisions that only apply to governments. This approach ignores the plain language of the treaty and would create unnecessary burdens in the context of property rights and harmful contamination.

Conforming to the treaty should not mean that what is forbidden to States Parties must be forbidden to private entities as well. The treaty doesn't say that. It only says that private entities must conform. First, when Article VI calls for private conformity to the provisions of the treaty, it leaves unsaid which provisions apply. A review of the treaty shows that most of it applies to "States Parties." When the treaty's drafters meant a provision to apply to non-governmental entities they said so, such as in the non-interference provision of Article IX. Accordingly, when we determine to which provisions a private entity must conform, we see that very few apply to private actors.

1. Private property. Legal certainty would help investment is the context of private property rights in outer space. Clear and recognized freely transferrable property rights lie at the heart of Western prosperity:[xxi]

> Absent legally recognized rights to buy, own, and sell titled property, it is difficult, if not impossible, to get a loan to purchase said property, improve it, mine it, drill for minerals on it, or sell the proceeds from any of those activities. Property rights are a sine qua non of wealth creation … .[xxii]

For US companies, Congress resolved one-half of the uncertainty by recognizing private claims to extracted resources when it passed the Space Resource Exploration and Utilization Act of 2015. The question of what property interests a private entity may exercise or what right it may have against someone with a competing claim to terrain carries less certainty. Many scholars and government officials interpret the outer space treaties as barriers to private property under different theories. A careful reading of the treaties, however, shows that contrary theories may better reflect what the treaties actually say.

Additionally, what the treaties have to say about the permissibility of private property rights remains a question of first impression. This means that all the scholarly articles, the different position statements from federal agencies, the wishes of space pioneers, have not been put through the crucible of litigation, and no judge has rendered a decision as to the accuracy of those interpretations.

Accordingly, because a question of first impression is one where no binding legal authority controls the answer, it might help to take a fresh look at the permissibility of private property rights under the Outer Space Treaty.

There are several theories under which private entities may not claim property in space: a theory of the commons, the Outer Space Treaty's bar to national appropriation, and a desire to forbid to private entities whatever is explicitly forbidden to states through theories of conformity or responsibility. There are an equal number of responses.

a. Space as a commons. Many argue that space is a commons because it is "the province of all mankind" under the Outer Space Treaty or the "heritage of mankind" under the Moon Treaty. As the work of Professor Henry Hertzeld of George Washington University and Christopher Johnson and Brian Weeden of the Secure World Foundation shows, this is not correct. What really constitutes the "province of all mankind" is not outer space but the activity of exploring and using it.

Article I of the Outer Space Treaty says:

> The exploration and use of outer space, including the Moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic and scientific development, and shall be the province of all mankind. Outer Space, including the Moon and other celestial bodies, shall be free for exploration and use by all States without discrimination of any kind, on a basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies.

These scholars explain that, when read properly, it is exploration and use of outer space that is

the province of all mankind, not outer space itself. Additionally, since the United States has not signed the Moon Treaty, and most spacefaring nations have not, there is no need to explore the meaning of common heritage.

b. Bar on national appropriation Some suggest that the Outer Space Treaty's Article II, which prohibits national appropriation of outer space, including the Moon and other celestial bodies, means that no one may appropriate space. The quick answer to this is that the treaty prohibits national appropriation, not all appropriation or private appropriation.

c. Imputation of treaty prohibitions on state actors to private actors. Some claim that Article VI's provision that States Parties to the treaty assure "that national activities are carried out in conformity with the provisions set forth in the present Treaty" means that commercial actors must abide today, even absent legislation, by each provision in the treaty, even the provisions that only apply to governments. This approach ignores the plain language of the treaty.

Conforming to the treaty should not mean that what is forbidden to States Parties must be forbidden to private entities as well. The treaty does not say that. It only says that private entities must conform. When Article VI calls for private conformity to the provisions of the treaty, it leaves unsaid which provisions apply. A review of the treaty shows that most of it applies to "States Parties." When the treaty's drafters meant a provision to apply to non-governmental entities they said so, such as in the non-interference provision of Article IX. Accordingly, when we determine to which provisions a private entity must conform, we see that very few apply to private actors.

Article II's bar on national appropriation may have other interpretations, some of which are less burdensome for the private sector than a ban on recognizing private property rights. Indeed, to the extent that Article VI calls for conformity by private actors, a less burdensome interpretation would be that private actors may not serve as a conduit for national appropriation. Accordingly, state owned enterprises would not be able to appropriate parts of outer space, but private entities could.

In this same vein, others argue that Article VI's statement that "States Parties to the Treaty shall bear international responsibility for national activities in outer space... whether such activities are carried on by governmental agencies or by non-governmental entities..." means that what is forbidden to states must be forbidden to their citizens. Again, this theory ignores the plain language of the other provisions, which for the most part only apply to States Parties. The fact that an entity may be financially responsible for someone else does not automatically mean that what is forbidden to the first entity is forbidden to the second one. Person A may be responsible for Person B's debts, but when Person A loses his driver's license, Person B may continue to drive.

Accordingly, when we interpret Article II's bar on national appropriation, we see that it does not ban private appropriation. Although the U.S. State Department once claimed that "private ownership of an asteroid is precluded by Article II,"[xxiii] the U.S. Congress

has since exercised its legislative authority to override and disagree at least in part when it passed the Space Resource Exploration and Utilization Act of 2015. That new law recognized the rights of private entities in resources they may extract from outer space.[xxiv]

2. Harmful Contamination. The treaty offers another question of first impression in the form of Article IX's admonition that States Parties to the treaty avoid "harmful contamination" of outer space and adverse changes in the environment of Earth. There are two questions at issue here. Does the admonition apply to non-governmental entities? Does harmful contamination mean the same thing as planetary protection?

a. Applicability to the private sector. The first reason to question the applicability of the so-called "planetary protection" provision is that the treaty itself limits this requirement, like many others, to "States Parties." States Parties are governments. As noted above, when the drafters of the treaty intended a particular provision to apply to non-governmental entities they said so.

Secondly, even if it applied to the commercial sector, Article IX's harmful contamination provision is not self-executing. It requires the legislative branch, Congress, to make numerous policy judgments, such as whether the goals of space science or space settlement should preempt one another or may be pursued together.

b. Article IX does not require "planetary protection." Article IX warns against "harmful contamination." NASA's "planetary protection" policy[xxv] is the term "given to the practice of protecting solar system bodies (*i.e.*, planets, moons, comets, and asteroids) from contamination by Earth life, and protecting Earth from possible life forms that may be returned from other solar system bodies." Additionally, NASA states that its policy is designed "to preserve our ability to study other worlds as they exist in their natural states." As a science agency that is part of the U.S. Government, NASA has interpreted Article IX of the Outer Space Treaty to mean that the agency's own missions must not only avoid what the ordinary person might consider harmful contamination—no toxins, no Agent Orange, no peanuts—but microbial contamination as well. NASA tries to limit the presence of bacterial spores on any out-bound surface to no more than 300,000. Accordingly, NASA requires the sterilization of its spacecraft to avoid bringing microorganisms to Mars. The European Space Agency follows similar measures NASA is being a good steward with this approach, and its policy is designed to enhance scientific study.

The treaty, however, would have NASA only avoid "harmful" contamination, not all contamination. Thus, NASA's planetary protection policy provides one interpretation of what the treaty means but not the only interpretation.

With this in mind, we must recognize that Congress has told NASA that the agency's long-term goals must enable the extension of a human presence beyond low-Earth orbit and into the solar system, "including potential human habitation on another celestial body and a thriving space economy in the 21st Century."[xxvi] More explicitly, Congress

told NASA to work toward eventual "human habitation on the surface of Mars."[xxvii] People are covered in bacteria, and yet the law says NASA must work to enable a human presence on Mars.

Logically, Congress having determined that a human presence in space is desirable, anything with equivalent or less biological baggage than a human being should not be required to undergo the expensive sterilization protocols now employed for government missions even if the United States had agreed to apply the harmful contamination provision to commercial operators. It might be time to recognize that a Congressional mandate overrides an agency policy.

In sum, the Outer Space Treaty may be interpreted to allow recognition of private property rights, regulation only when sufficient hazards exist to warrant the expenditure of government resources, and that the harmful contamination provisions only apply to States Parties, not to private operators.

Thank you for the opportunity to contribute to this discussion.

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[i] Commercial Space Launch Act, 51 U.S.C. ch. 509.
[ii] Federal Communications Act of 1934, 47 U.S.C. §§ 153(42), 301, 303, 307, 309 and 332.
[iii] National and Commercial Space Programs, 51 U.S.C. §§ 60101, 60121.
[iv] 51 U.S.C. § 50919 (g).
[v] *Streamlining Regulations on Commercial Use of Space,* Space Policy Directive-2, Presidential Documents, 83 Fed. Reg. 24901 (May 30, 2018), https://www.whitehouse.gov/presidential-actions/space-policy-directive-2-streamlining-regulations-commercial-use-space/ (Space Policy Directive-2).
[vi] Space Policy Directive-2 at sec. 1.
[vii] 51 U.S.C. § 50904(c).
[viii] https://groundbasedspacematters.com/wp-content/uploads/2019/05/CRPT-105hrpt347.pdf
[ix] In the interests of brevity, the reader may assume that, unless otherwise indicated, references to "outer space" always include the Moon and other celestial bodies.
[x] Outer Space Treaty, Art. II.
[xi] Outer Space Treaty, Art. VI.
[xii] Outer Space Treaty, Art. IX.
[xiii] *See e.g.*. Gbenga Oduntan, *Who Owns Space? U.S. Asteroid Mining Act is Dangerous and Potentially Illegal*, The Conversation, Nov. 25, 2015 https://theconversation.com/who-owns-space-us-asteroid-mining-act-is-dangerous-and-potentially-illegal-51073 (Last visited Sept. 3, 2017)(contesting the international legality of the U.S. recognition of private property rights in resources extracted from outer space as contrary to "settled principles of space law," which include "the prevention of unilateral and unbridled commercial exploitation of outer-space resources" under the Outer Space Treaty and the Moon Agreement of 1979.).
[xiv] Report from the Executive Office of the President, Office of Science and Technology Policy, to Chairmen Thune and Smith, 3 (Apr. 4, 2016). Available at https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/csla_report_4-4-16_final.pdf .
[xv] Fact Sheet—Moon Express Payload Review Determination, FAA, (Aug. 3, 2016) available at https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=20595 (Last visited Sept. 3, 2017).
[xvi] Laura Montgomery, *U.S. Regulators May Not Prevent Private Space Activity on the Basis of Article VI of the Outer Space Treaty,* Mercatus Working Paper, Mercatus Center at George Mason University,

Arlington, VA, 2018, https://www.mercatus.org/system/files/montgomery-outer-space-treaty-mercatus-working-paper-v1.pdf.

[xvii] Report from the Executive Office of the President, Office of Science and Technology Policy, to Chairmen Thune and Smith, 3 (Apr. 4, 2016). Available at https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/csla_report_4-4-16_final.pdf .

[xviii] Fact Sheet—Moon Express Payload Review Determination, FAA, (Aug. 3, 2016) available at https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=20595 (Last visited Sept. 3, 2017).

[xix] *Medellin v. Texas,* 552 U.S. 491, 526, 128 S.Ct. 1346, 1357 (2008).

[xx] *Medellin*, 552 U.S. at 529 , 128 S.Ct. at 1371; see also Ted Cruz, *Limits on the Treaty Power*, 127 HARV. L. REV. F. 93 (2014), http://harvardlawreview.org/2014/01/limits-on-the-treaty-power/

[xxi] Rand Simberg, *Homesteading the Final Frontier, A Practical Proposal for Securing Property Rights in Space*, Competitive Enterprise Inst., http://cei.org/sites/default/files/Rand%20Simberg%20-%20Homesteading%20the%20Final%20Frontier.pdf (Apr. 2012)(Last Checked Sept. 6, 2017) *citing* Hernando de Soto, *The Mystery of Capital: Why Capitalism Triumphs in the West and Fails Everywhere Else* (New York: Basic Books, 2003).

[xxii] *Id.*

[xxiii] Virgiliu Pop, *Who Owns the Moon? Extraterrestrial Aspects of Land and Mineral Resources,* p. 42 *quoting* Letter from Ralph L. Braibanti, Director, Space and Advanced Technology, U.S. Department of State/Bureau of Oceans and International Environmental and Scientific Affairs (Aug. 15, 2003).

[xxiv] 51 U.S.C. § 51303.

[xxv] Office of Planetary Protection, https://planetaryprotection.nasa.gov/overview (last checked July 23, 2019).

[xxvi] 42 U.S.C. § 18312.

[xxvii] 51 U.S.C. § 70504(b).

Laura Montgomery
Ground Based Space Matters, LLC
Law Offices

Laura Montgomery teaches space law at Catholic University's Columbus School of Law. In her private practice she specializes in regulatory space law, with an emphasis on commercial space transportation and the Outer Space Treaties. She provides expert opinion on the Commercial Space Launch Act, its implementing regulations governing the launch of launch vehicles, the reentry of reentry vehicles, the operation of launch and reentry sites, and the financial responsibility and liability requirements of those regulations. In 2017, she testified to the Space Subcommittee of the House Committee on Science, Space, and Technology, and to the Senate Committee on Commerce, Science, and Transportation's Space Subcommittee on Space, Science and Competitiveness on matters of regulation and international obligation. She has published articles on the Outer Space Treaty, human space flight, and launch safety. She writes and edits the space law blog **GroundBasedSpaceMatters.com**.

Ms. Montgomery spent over two decades with the Federal Aviation Administration. She served as the manager of the Space Law Branch in the FAA's Office of the Chief Counsel. Before that, she was the FAA's Senior Attorney for Commercial Space Transportation. As the FAA's space lawyer, she supported the Office of Commercial Space Transportation in its authorization and regulation of launch, reentry, and the operation of launch and reentry sites, popularly referred to as spaceports. Her work at the FAA included legal interpretations, the development and application of regulations, legislative proposals, identification of matters for enforcement action, financial responsibility questions, and legal review of licensing and permitting evaluations. Her rulemakings included human space flight, explosive siting, launch and launch site licensing and safety, experimental permits, lightning protection, and financial responsibility. She addressed a wide range of issues, from amateur rockets, to sea launch, to space balloons.

Highlights from Ms. Montgomery's time at the FAA include her representation of the FAA at the United Nation's legal subcommittee of the Committee on the Peaceful Uses of Outer Space, her service as chair to an inter-agency working group on space property rights at the request of the Office of Science and Technology Policy in the White House, and testimony to Congress on the FAA's interpretation of the Commercial Space Launch Act.

Before working for the government, she was in private practice with Arter & Hadden in Washington, DC, where she specialized in telecommunications, administrative law, and appellate work.

She received her law degree from the University of Pennsylvania, and her undergraduate degree with honors from the University of Virginia.

Chairwoman HORN. Thank you, Ms. Montgomery, and thank you to all of our witnesses. We will now begin with questions, and I recognize myself for 5 minutes.

This is clearly an important issue. There are many questions that we need to answer, and, to all of the panelists, thank you for being here. Your testimonies have raised a number of important issues, including streamlining regulations, understanding the uncertainties and risks, and considering contracting and procurement options, the role of innovation, emerging markets and services, and we could go on. And one of the purposes of this hearing today is stage-setting, to identify the types of challenges and opportunities that we need to tackle as the space industry moves into really a new generation. And it's important that we have full insight into what these issues are to delve deeper.

So, as we want the industry to succeed, and we want to get it right from the regulatory, and from our role as an oversight committee, I'd like to hear from all of witnesses, very briefly, your top two priorities unto what the Subcommittee looks at to delving further into the commercial space activities and issues. So I'll just start, and we'll go down. Dr. Lal?

Dr. LAL. Sure. I would say that the top two priorities ought to be looking at alternative mechanisms of contracting with commercial entities—many small companies, startups, do not have the ability to have the background for the kind of contract that are traditionally used—and the second one is to understand that there may not be, at least in the near term, private markets, and therefore there is more supported needed from the government to support emerging commercial companies.

Ms. CHRISTENSEN. I would say, first, working with startup and early stage companies in an effective way, and finding a path to manage the business uncertainty they face with the technology and capability innovation that they bring to the table that the government can generate value from, and second, more broadly, thinking about leveraging the commercial investment that we see today across space markets.

Mr. STALLMER. I think in the near term the most challenging regulatory hurdle we have in front of us right now is this NPRM, as we're looking at how the launch industry is regulated, and the effort to streamline this. The current rule, as it's proposed, it really causes a lot of barriers to the innovative companies that are entering the launch market. When you look at the global space economy, launch is only a small part of it, but really is a critical part to enable the success of this whole great commercial—global space marketplace. And I'd also agree with Dr. Lal on the contracting mechanisms, and how we procure services. I look to the model of the commercial off the shelf products—or—with the COTS regime that we've used in the past, leveraging the private sector with that type of investment, and—having—both parties have skin in the game. I think that's really critical.

Mr. FRENCH. The first one I would have is the Committee looking at a multi-year NASA authorization, and through that, being able to provide guidance on many of these issues, including the purpose and mission that NASA should have between its national programs and the purchase of services. I'd say a second one would be, as I

mentioned in my oral testimony, spectrum. I mean, spectrum is the invisible nervous system of space, and without it we can't talk to our satellites, and they can't talk back to us. Thank you.

Ms. MONTGOMERY. Looking at it from a legal perspective, I think my interests and priorities would be more long term, in terms of encouraging investment, and regulatory certainty going forward, for the private community. And in that regard, I would strongly recommend that Congress set to rest concerns that the executive branch has the ability to usurp Congress's legislative role by denying private actors access to space under Article 6 of the treaty. The second one I would strongly urge you all to consider is setting forth some sort of criteria by which we would be able to recognize private actors' ability to own land on celestial bodies, whether through principles of adverse possession, or otherwise. I think it is something that Congress wants to take into account for long-term purposes.

Chairwoman HORN. Thank you all. So, with the little time we have left, Ms. Christensen, I want to focus on a piece of your testimony. You noted that the price of leveraging investor-funded dynamic innovation is uncertainty. And, in terms of the government's mission—and, Mr. French, you also commented on the need for a detailed assessment, and clear pre-defined determination of government versus industry responsibilities. And, in considering public investment, and the private service model for procurement for government missions and certain elements, especially those that might involve human safety, what are the guard rails that we can put in place to appropriately manage these risks, and how can we ensure that the government aligns its decisions in leveraging innovative capabilities with the potential risk to the taxpayer, and to mission assurance, as well as human risk? And we have very little time left, so I'll let you both briefly answer that.

Ms. CHRISTENSEN. Very quickly, implementing acquisition processes and partnering mechanisms that recognize, and specifically address, the business uncertainty associated with early-stage companies will help the government benefit while managing risk.

Mr. FRENCH. And I'd say it starts with what does the government want out of the program, and what is that—what is its—what is the core priority? And then, from there, optimizing around that, instead of—when you have multiple goals, you can sometimes lose sight of a primary risk, such as human safety.

Chairwoman HORN. Thank you. I now yield to my distinguished colleague, the Ranking Member, Mr. Babin, for 5 minutes.

Mr. BABIN. Thank you, Madam Chair, I appreciate it. Mr. Stallmer, Chairwoman Horn entered into the record the Coalition for Deep Space Exploration's letter supporting the FAA's NPRM for commercial space launch and re-entry. However, your testimony highlights several issues with the FAA's proposed regulations. From your perspective, would these regulations advance U.S. leadership in commercial space, or set us back? And if they would set us back, do you see a viable path to fixing that?

Mr. STALLMER. I think the regulations, as they're currently written in this draft, would definitely set us back. It's not—it's—it tends to be more of the status quo. In a dynamic environment, where innovation is occurring with new launch entrants, it creates

more burdens for a lot of these new entrants, and especially in different categories. These rules are primarily written for expendable launch vehicles, you know, which is more the legacy of the launch industry. It doesn't take into account capture/carry hybrid reusable vehicles. So I think there's a path forward with recommendations that we've made that could benefit all the launch providers.

Mr. BABIN. I got you. They need to be modernized a little bit for——

Mr. STALLMER. I think updated——

Mr. BABIN [continuing]. Usable——

Mr. STALLMER [continuing]. With the changing times.

Mr. BABIN. OK. All right. Thank you. And, Ms. Montgomery? The U.S. Senate recently passed legislation to protect the Apollo landing site. A companion bill was introduced in the House to commemorate Apollo 11. The bill would regulate private sector activity based on NASA policies without following the *Administrative Procedures Act*. It would also direct the Administration to negotiation an international agreement to protect the sites. This is a very laudable goal, but is this the best way to conserve the sites?

India recently launched a lander to the south pole of the Moon, and, if all goes well, presumably they would want to protect their first landing site. Could this bill set a precedent that precludes U.S. exploration of the lunar south pole, for instance, where there's billions of tons of water, and serve as a back door way of "staking a claim" to regions on the Moon? Your comments?

Ms. MONTGOMERY. This is an issue that has only been something I've recently thought about, so these are more recent thoughts. One concern I would have about the way the bill works is that internationally there may be some concern that attempts to set up an exclusion zone could constitute national appropriation, and so I don't know where the thinking is on that, but it would certainly be something to explore as a possible concern under the Outer Space Treaty, because the—Article 2 does bar national appropriation. Second, I would worry about whether it allows for emergency landings, because it—some of those policies may not allow that. My third concern with it is that both bills provide that the NASA policy would apply, and NASA is not a regulatory agency, and—so it is not—the policies have been written without going through the notice and comment period.

Mr. BABIN. All right, thank you. And, Mr. French, the Department of Defense developed the Atlas and Delta launch vehicles with 75, 80 percent of funding coming from the contractors, and only 20 to 25 percent coming from the taxpayer. NASA developed the commercial cargo program by sharing their development costs with SpaceX and Orbital Sciences 50/50. SpaceX and Boeing currently receive 90 percent of their development funding for the Commercial Crew Program from the taxpayer. NASA recently announced that the lunar landers will also be funded by the taxpayer at least 90 percent. The rationale for the early partnerships was that contractor could also sell to other customers, which would lower the government's cost.

The success of such an approach is dependent upon the potential market outside of the U.S. Government. There appears to be a market for robotic landers, but is there a market outside of NASA

for human-rated lunar landers that could defray the cost of the government, and justify a public-private partnership at this point?

Mr. FRENCH. Thank you, sir. There is—there's no current market in this area, unlike the case of the multibillion dollar commercial launch market, and so it raises that risk of are you possibly excluding some pretty capable companies if you're requiring to put money in an area where they don't—aren't able to realize return in a 5 to 7 year period where they have to make those decisions.

Mr. BABIN. OK. Thank you very much. And I am expired, so I'll yield back. Thank you.

Chairwoman HORN. Well, it looks like you're still here, but your time is up, so—don't go anywhere.

Mr. BABIN. All right.

Chairwoman HORN. We like having you around. Mr. Crist, you're recognized 5 minutes.

Mr. CRIST. Thank you, Madam Chair, and thank all of you for being here today. Maybe sort of an out-of-the-box question, but who are the three largest players in commercial space today? For any of you, or all of you to answer. Since this is 101.

Dr. LAL. Well, I think, again, if you go by the definitions, and, again, as Mike French said, you know, Lockheed-Martin's, you know, can be considered no less commercial than SpaceX, or Blue Origin. But if you were to define commercial space as, you know, newer companies that are using more fixed-price type contracts with the government, I would say SpaceX, Blue Origin, Planet, maybe some of the bigger commercial companies. Though, obviously, as I said, Lockheed, Boeing, Northrup are commercial as well.

Mr. CRIST. Right.

Ms. CHRISTENSEN. So I'll add to that the very sizable satellite operators such as, SES, IntelSat. AT&T operates direct-to-home television capabilities. Those are very substantial commercial companies operating in space. Thinking about human space flight, and—on-orbit activities, there, just as Dr. Lal said, the major companies, Lockheed-Martin and Boeing, Northrup Grumman. And looking at the venture-funded firms, the companies that have specifically had in their history this new kind of investment financing, I would say that the largest is SpaceX by far. That's a very widely accepted unicorn, a company with more than a billion dollars in valuation. They're well over 30 billion at this point in valuation, a privately held company. Blue Origin, and then the satellite startup OneWeb, which has received very substantial investment, several billion dollars to design and deploy a global broadband satellite constellation using small satellites.

Mr. STALLMER. And I would concur at a lot of the, you know, if you look at the different segments, you know, from the commercial satellite to commercial launch, you know, what—we often talk about SpaceX, and what Blue Origin's doing, and Virgin Galactic, and Sierra Nevada Corporation. And certainly, you know, companies that are involved with these—the commercial cargo and the commercial crew, you know, they view themselves as well as commercial companies. So there's many different definitions to what a commercial company is. And I won't rank order of them, because I have 85 of them. I think they're all great.

Mr. CRIST. You ought to know it better than anybody.

Mr. FRENCH. You know, in my view, I'd look at, you know, first I'd say does the company have an active business——

Mr. CRIST. Right.

Mr. FRENCH [continuing]. Dealing with the commercial sector outside the U.S. Government, and then, if you meet that threshold, then how big is it? How much is its revenues? Does it have profit? Many of these companies don't have profit. And in that case, it's Lockheed-Martin, Boeing, and Northrup Grumman with those criteria.

Mr. CRIST. And, Ms. Montgomery, I might have a little different question for you, if you don't mind. You touched on the treaty, and how we handle, I guess, property that's in space. And could you elaborate, and sort of explain to us what this treaty is, who the parties to it are, how it has authority to exist?

Ms. MONTGOMERY. Sure. Back in 1967 the major spacefaring nations, principally the United States and the USSR, signed the Outer Space Treaty, and it is something that has been signed by most countries, including all of the major spacefaring nations. So that includes Russia——

Mr. CRIST. India, China——

Ms. MONTGOMERY. Right, India, China, Australia, U.K., everyone. It has a provision in it, under Article 2, that bars national appropriation, and I always emphasize that national, because a lot of people take different parts of the treaty and say, well, if this treaty bars governments from appropriating, it must also bar private actors from appropriating outer space. So I disagree with all that, and I've laid out all the theories in my written testimony, but you probably don't want me to——

Mr. CRIST. Why do you disagree with that?

Ms. MONTGOMERY. Well, first of all, just a plain reading of the text says national appropriation, and I am not a nation-state, so if I could get up there and establish some adverse possession, maybe I'd have a claim.

Mr. CRIST. Like homesteading?

Ms. MONTGOMERY. Sure, exactly. And I think that it would be useful for the United States to look at some form of homesteading in order to be in accordance with the treaty——

Mr. CRIST. Well, we did it for the United States.

Ms. MONTGOMERY. Right. I've seen some clever theories presented, one of which is that you would recognize adverse possession rights of a person or company of any nationality, and that that should accommodate certain concerns under the treaties. So, you know, we look at property rights in outer space in two ways. One is extracted resources, like mining, you know, pulling fishes from the sea, taking platinum group minerals from the craters of the Moon, or water, which might be more valuable.

And that, I think, the United States has settled domestically, and Luxembourg has copied the United States by saying, we're going to recognize the rights of people who commit their labor and extract resources from the Moon or asteroids. Where the uncertainty still remains is on terrain. This is a long-term concern, but I think that, with the advent of venture capital, and people willing to take risks, I think they might be willing to take more risks with

their money if they think that they can get a return, if they can mortgage and put up for collateral any land that they obtain, alienate, you know, sell it, transfer it, lease it. All of these things are valuable abilities, rights, that probably will help incentivize a lot of activity. And we can look at our own history to see how private property has led to prosperity. I think the same would hold going into the future.

Mr. CRIST. With the Chair's indulgence, just a quick question, because my time is up, but the 1967 treaty, was that ratified by the Congress?

Ms. MONTGOMERY. Yes, by the Senate. Yes.

Mr. CRIST. Thank you. Thank you, Madam Chair.

Chairwoman HORN. Thank you, Mr. Crist. And before I recognize our next Member for questioning, I have a presentation for Mr. Olson, who kindly pointed out in our last hearing that we were rapidly approaching OU-Texas, and I think you need some decoration for your office to prepare you, so——

Mr. OLSON. Paybacks——

Chairwoman HORN. I know. You should be careful what you start. He needs, you know, some good——

Mr. OLSON. Boomer sooner.

Chairwoman HORN. Boomer—yes, boomer sooner. He needs something to remind him of who's going to come out on top of the Red River Rivalry. I'm not, but, you know, I am an Okie through and through, so I can't allow, you know, my friend from Texas to take over. Yes——

Mr. WEBER. So, Madam Chair, apparently in this Committee there's still space for fun.

Chairwoman HORN. Yes. I like it. Mr. Olson, you're recognized for 5 minutes.

Mr. OLSON. I thank the Chair. Hook 'em. Welcome to our five witnesses. My district sits in the shadow of the Johnson Space Center, the home of human space flight. In 2015, the FAA approved the Houston Spaceport. It's a commercial launch port being built in Texas 22, at Ellington Joint Reserve Base, right there in my district. That's the base that most of the flight training crafts at JSC, what they've done there, they've got some military operations there, some helicopters, the Coast Guard. They fly drones out of there with the Army. Last month they announced their first phase of construction for the spaceport, basically the infrastructure of the streets, the water, the electricity. The City Council there in Houston has approved $18.8 million this past October for that infrastructure build.

Their vision is to launch microsatellites from the spaceport there, help out with astronaut training, zero-G training, get rid of the vomit comet, they call it, that bird that just flies for about 30 seconds down they can't train. This can make a lot more training. They actually want some space tourism. Follow the flight that Alan Shepard, you know, into space, sub-orbital, go up for 10 minutes, come back down, fly over the Gulf of Mexico. It's a great operation. They've got two tenants already there. They've got Intuitive Machines. They've been selected by NASA to build what's called the Nova-C. That's a vehicle that's going to the Moon by 2021, is the current plan. They've also got Trumbull Unmanned, which builds

UAVs (unmanned aerial vehicles). As you know, those guys are good for data collection, and they were great during Hurricane Harvey to see levees, and people trapped real time.

And so my point is, in these companies there, got a lot of companies in Houston, and all across the country, that are making great strides on commercial spaceports like that, and commercial space. We've proven that commercial flights to the Space Station, cargo, are working, no doubt about that. I expect crew flights, human flights, to the space station with commercial vehicles will not be a problem sometime, Mr. Stallmer, later this year. My question is, since we're doing commercial rockets to the space station for cargo, and soon crew, how about we turn over the space station to the commercial sector? Is that a good idea? There's been challenges we should know about? How about making it all private? The space station, the vehicles that go up there, humans, cargo?

Mr. STALLMER. I certainly appreciate your endorsement of that, and I think in time we may be there. I think NASA has been an excellent partner on the space station. You see the great work that the ISS National Labs have been doing, formerly known as CASIS, on opening the commercial marketplace on the International Space Station, what NanoRacks is doing, Made In Space. So the commercialization of the space station is slowly growing, and someday that may be the case, that they turn it over to the commercial sector, and I think eventually we will see routine commercial flights to the International Space Station. So I'm very enthusiastic about the work that's being done, but one thing we do need is the certainty that the space station will be there so we can, you know, work to greater commercialize it.

And as far as the operations going on, Houston and Ellington Field, I think it's a model for what is going on in other spaceports, the diversity of operations that they have going on in bringing in these new customers. And we see this with many—we—of the 12 spaceports that we have here in the U.S., what they're doing, the diversity of bringing in a variety of companies, and the testing that's going on, and the flights that are going on. It's not just limited to the East Coast and West Coast ranges, which are also doing fantastic work.

Mr. OLSON. I forgot to mention too, education. San Jacinto College has set up operations there at the spaceport to train future technicians to do the manufacturing, to run that spaceport. So, again, private sector, private sector, private sector. Another question for you, Mr. Stallmer, looks like we've got low-Earth orbit pretty much settled for commercial. I don't think that's a big problem. But how about beyond low-Earth orbit, going to the Moon? I know that's a long way off, but we've been preparing for commercial vehicles and commercial crews to take us to the Moon, and maybe Mars, and make this whole endeavor commercial?

Mr. STALLMER. NASA set out—has set out a great vision with the Artemis Program about bringing—the next step going back to the Moon, and I know that the commercial sector is going to play a major role in landers, ascent vehicles, robotics, and even with the gateway, as we go down that step. So I think the role—and that partnership with NASA and the commercial sector is going to en-

able us an affordable basis to do that, to further our deep space exploration.

Mr. OLSON. Thank you. I'm out of time. One further question, can you sing "The eyes of Texas are upon you"?

Mr. STALLMER. I am going to work on that one, Congressman. Being a northeasterner, we don't do that.

Chairwoman HORN. The Chairwoman would suggest——

Mr. OLSON. Or Texas fight——

Chairwoman HORN [continuing]. That's not the best idea.

Mr. OLSON [continuing]. Texas fight?

Mr. STALLMER. Yes. Congressman Waltz will probably want me to sing the VMI alma mater song at some point, so I've got a lot of work to do in front of me on that one, but I appreciate the challenge.

Mr. OLSON. Thank you. I yield back.

Chairwoman HORN. That may be a slippery slope, I think. The Chair recognizes Mr. Perlmutter. You're not going to start singing, are you?

Mr. PERLMUTTER. Fight, CU, down the—no, I'm not.

Chairwoman HORN. Yes.

Mr. PERLMUTTER. So, Mr. Olson, it's so nice to have you back on this Committee, I have to say that. It's very important that you're on this Committee now, that's a whole other story. So, Professor, I want to talk to you about space law for a second, because I was a litigator for a long time. I did a lot of real estate, securities, that kind of commercial litigation, and I appreciate your comment about the potential for the venture capital companies to want to invest some more, but I guess I'm more concerned that there isn't a body of law. I mean, you say adverse possession. I don't know if the Russians have adverse possession, whether they consider that part of the law, or, you know, exactly how you mortgage, you know, in Japan. And whether or not the Space Treaty—and what I am concerned about is whose body of law controls? Is it the law the sea, is it something that in my opinion, we've really got a lot of work to do on it if, in fact, we're going to try to retire some of the risk. And I'd just like your comment, and Mr. French you may comment on it too, if you will, and then I've got some questions about going to Mars.

Ms. MONTGOMERY. Well, I did read a marvelous article by a professor from South Dakota, I think he was Simmons, who talked about how the adverse possession can be viewed through a Marxist lens. So perhaps it is possible for us to persuade the Russians that adverse possession might be a tenable approach for recognizing property rights in outer space.

But I think—one of the other points he made, and I think it was a good one, was that this could all develop organically. You know, one approach would be for you all to set up some statutory criteria, but otherwise we could see cases in court between two U.S. companies, and they go to court because they—just finally gotten too close to each other, and they're annoying each other, so now they want it resolved. And, if they're U.S. companies, they'll go to a U.S. court.

Mr. PERLMUTTER. Does the Space Treaty——

Ms. MONTGOMERY. Internationally——

Mr. PERLMUTTER [continuing]. Establish any kind of a framework if there is conflict between, you know, two individuals, or two countries, as to who has a claim, and that the other guy's jumping the claim?

Ms. MONTGOMERY. Not for claims, no. Mostly it's—if there's conflicts internationally between countries, you have diplomatic talks. But not for individuals, and I do not know—I do not believe there's one for claims in land.

Mr. PERLMUTTER. OK. Just personally, you know, we passed the *Space Resource Exploration and Utilization Act of 2015*, which I think gives a little bit, but, for me, I think we've got just a lot more work to do, and I'm speaking as somebody who had to go try these cases. You know, and that's where we have a complete body of—or a pretty good body of law here in the United States about who owns what, and who has certain rights to those kinds of things.

Let me change the subject for a second, because, as you all know, my goal on this Committee is to help continue to push us to getting our astronauts on Mars by 2033, when the orbits between the Earth and Mars are the closest. And so, to Dr. Lal, to Mr. Stallmer, what kind of interest is there in the commercial sector on a major mission of that sort? I personally think it's got to be international in scope, and public-private, and I hope to see NASA in the lead, but how do you see this developing from the commercial sector?

Dr. LAL. So, about a year or so ago, at the mandate of this Subcommittee, and at the request of NASA—wrote a report on evaluating the prospects of getting to Mars by 2033, and we found that that is not feasible, as you know——

Mr. PERLMUTTER. If we don't fund it.

Dr. LAL. Especially——

Mr. PERLMUTTER. That was one of the assumptions in there.

Dr. LAL. But to specifically answer your question, you know, commercial entities would be just as happy to take the money as anybody else. There's no, you know, there's no pushback from commercial sources to get to Mars. The important thing to mention is that some of the activities that need to happen, you know, the linchpin of the Mars mission is the deep space transport, the DST. It's a very complicated piece of machinery. It needs to keep humans alive for 1,100 or more days. It needs to have a power and propulsion system that it—that can get it there and back, and it needs to have an—system that is—that we do not have. It needs to have almost complete, 100 percent, recycling of air, oxygen, et cetera.

These are just very difficult things to do on fixed-priced sorts of budgets, because they're high-risk, and cost-plus contracts seem to be better for these——

Mr. PERLMUTTER. It's kind of a new venture?

Dr. LAL. Yes. I think——

Mr. PERLMUTTER. Mr. Stallmer?

Mr. STALLMER. I would say we can't get there if we don't start soon. You know, 2033, you put a date out there, and we work to that. There are technical challenges, but I can tell you that I have two individuals that are quite passionate about getting to the Moon and beyond, and are willing to back that financially with their own personal net worth, and are developing systems, and have that vision. But you have to build that infrastructure as a stepping stone

to that vision, and I see that with the lunar program, with Artemis, and that's a stepping stone onto Mars. But, as I said, we can't get there until we start.

Mr. PERLMUTTER. Thank you. I yield back.

Chairwoman HORN. Thank you, Mr. Perlmutter. The Chair now recognizes Mr. Waltz for 5 minutes.

Mr. WALTZ. Thank you, Madam Chair. Recently had the chance to take my family down to the Cape for the amazing celebration of Apollo. And, in conversations with my daughter and family, they were astounded, as much as their dad talks about space, and why we need to be there, they were astounded to learn that the United States cannot send humans, we cannot send American astronauts to space. And I think that's always worth repeating. I think that our dependence on the Russian RD-180 is unacceptable, Mr. Stallmer, and I sit on the Armed Services Committee and see the national security implications of this all the time.

So I know the Air Force is working in the right direction with the Launch Service Agreement contracts to improve our domestic capabilities. How can Congress help reduce this dependency also on the civilian side?

Mr. STALLMER. The dependency on foreign launch vehicles, or on innovation of developing newer technologies?

Mr. WALTZ. Well, specifically on the Russian-made rocket engines.

Mr. STALLMER. Well, I think we're moving beyond that. I think there's a limitation on how many more Russian engines can be used. But what I would focus on is the innovation that you're seeing from several U.S. commercial companies on building new technologies and new engines. The fact that we were, for many years, dependent on a Russian engine for one of our main rockets is—well, that's a political hot potato, but what we are seeing right now—SpaceX, Blue Origin, Vector, RocketLabs—kick me, because I probably can't name them all, the new—Virgin, in Sierra Nevada, the new entrants that are building new American technology, new engines that hasn't been done in 20 years. I think that's a tremendous breakthrough, and I think, with Congress' support, and the certainty on certain regulations, we will continue this innovative growth on this new technology.

Mr. WALTZ. Please, just in the interest of time, send over anything else for the record, and that's for all the panelists, that Congress can help with to get government out of the way of this innovation. We need to create a framework, and take the approach of creating a framework, that emboldens innovation from the private sector, and obviously within reason, and with safety first, but that gets out of the way, and any way we can be helpful, we stand ready to do so.

I have Embry Riddle Aeronautical University in my district. They're doing incredible work on space situational awareness and space traffic management. DOC, the Department of Commerce, recently announced they are beginning to accept space situational awareness data from DOD, Department of Defense, in order to provide a commercial storefront for the private sector, and our international partners. Commerce officials, to my understanding, have been clear they don't want to be, so to speak, a traffic cop in space.

How do we, and this if for anyone. Mr. Stallmer, I'll start with you, but how do we ensure the transfer of this responsibility from DOD to Commerce is done? And, again, without creating new levels of bureaucracy or regulatory burden.

Mr. STALLMER. You have to leverage the commercial tools that are out there on the marketplace right now. What satellite companies are using for their own space situational awareness, the space—what—the Space Data Association, what they're using, the commercial products that are readily available at an affordable cost. You don't need this long lead time development. You just need to procure commercial products that are existing on the market that everyone else in the world is using.

Mr. WALTZ. Are we doing that?

Mr. STALLMER. Some government agencies are doing that, and I think some government agents could be a lot more efficient in the way they procure commercial services.

Mr. WALTZ. OK. Again, for the record, on which government agencies, and which——

Mr. STALLMER. I'd be——

Mr. WALTZ [continuing]. Specifically we can——

Mr. STALLMER [continuing]. Be happy to provide you with that list.

Mr. WALTZ. Ms. Christensen, just in the time remaining, Bryce issued a report on Volusia County, in my district, on their commercial space supply chain characterization. So the report stated that since 2000, over 250 venture capital firms have invested nearly $14 billion in startup. The scale of this investment will have generational consequences for Florida's Space Triangle, the Cape, Daytona, Orlando. Can you describe how the space industry will create jobs up and down the supply chain, and those kind of spill-on effects across multiple industries?

Ms. CHRISTENSEN. I'm pleased to. The end products of the space businesses that are being funded by venture capital are often analytic services, communications technologies—capabilities that support and enhance a wide range of other businesses. For example, telecommunications services are critical to any number of small businesses that rely on flexibility and international access.

From those end users of downstream applications, jobs are created all the way back up through the supply chain—manufacturing, computing capabilities, test and evaluation, engineering services, technologists. And then a whole range of people and services that support companies in a growing ecosystem that is not directly space related, but that creates jobs for people in support industries, ranging from legal services and consultants, to food service workers, and people in communities that are seeing that growth.

Mr. WALTZ. Thank you. Madam Chair, I yield.

Chairwoman HORN. Thank you, Mr. Waltz. The Chair recognizes Ms. Wexton for 5 minutes of questions.

Ms. WEXTON. Thank you, Madam Chair, for yielding, and thank you to the panelists for appearing today. I represent Virginia, where we are proudly the home of Wallops Island, the MARS, the Mid-Atlantic Regional Spaceport, and the aerospace industry is very important to us. In particular, my district is home to what

was formerly Orbital, and is now Northrup Grumman, which developed the Antares and Cygnus, Antares rocket and the Cygnus capsule, for resupplying the International Space Station.

And it's a good example of—I think, Mr. French, in your testimony you talked about the public investment, private service model that we have seen in aerospace and commercial space flight. And as we, as legislators, really have to plan for the future, I guess the question I would have for you, Mr. French, and for you, Ms. Christensen, and it's kind of a two-part question. First, can you speak to the projections for the frequency and pace of launches from spaceports in the next decade, or couple decades? And, related to that, how can spaceports better prepare for the future users, and ensure that things will be successful for these businesses?

Mr. FRENCH. I'll start, and then I'll let Carissa give you the real data. First off, on the partnership with Northrup Grumman, then Orbital, is a great example of the right factors in place. There was an existing launch market that NASA could capitalize on, and make that partnership happen, and be successful. And I think you're seeing similar things—Wallops, I think, is doing a good job in thinking about that, as it partners strategically with different government entities to make it a sustainable launch site. So that's, sort of, I think a very good strategy from the Wallops perspective.

Ms. WEXTON. OK. And what do you foresee—is there anything else that we can do better, or what do you foresee in terms of the pace of launches coming out of spaceports in the future?

Mr. FRENCH. I think, from my perspective, the two that—you've got quite a bit of, you know, future demand in those programs you described. I think there's something like 65 launches planned with the NASA commercial crew and cargo programs that Northrup Grumman is a part of. And then I think you have a series of DOD launches that are likely expected, given how important space has become on the national security side.

Ms. WEXTON. OK. Thank you.

Ms. CHRISTENSEN. We are generally seeing—with regard to projections for the frequency and pace of launches—we are seeing increasing launches in recent years, and will likely in the next few years. That said, launch is often cyclical, particularly as we're seeing the launch of larger constellations, which then will launch, have a pause, and then need to be replenished. But in recent years, in the foreseeable future, we're seeing growth.

With regard to how spaceports can better prepare, I would note two things. One is building partnerships with launch providers, which is clearly an area of great success for Wallops, and the second is engaging with small satellite operators, who will have different needs than satellite operators that launch large satellites, with regard to on facility services, integration, and so on.

Ms. WEXTON. And is that because that's an emerging market that hasn't gotten enough attention recently, or——

Ms. CHRISTENSEN. Small satellite operators are the primary satellite recipient of venture funds, and small satellite startups and emerging firms are seeking to launch large constellations of small satellites, and they are reaching the point where they are ready to begin launching, and so those deployment challenges will start to be more and more important.

Ms. WEXTON. Very good. Thank you. And, Mr. Stallmer, I see that you serve in a number of roles within the FAA's rulemaking committees, including space launch and re-entry, and spaceports, as well as FAA's Commercial Space Transportation Advisory Committee. And one of the concerns I have is that—you may recall that at Wallops we had a pretty harrowing crash a few years back, and there seems to be some variance in the industry about how accident investigations are conducted for these commercial launches, in terms of who conducts the investigation, and whether the government—whether the industry is going to self-investigate, or if NASA's going to lead, or independently investigate. And so, as we look into these issues, how can we ensure that there's transparency in the safety process as we look to expand commercial space travel?

Mr. STALLMER. I think the best way for transparency is the partnership between both parties, whether it's, you know, with a government facility, a launch facility, and the launching party. So if, for instance, with Orbital ATK, working closely with NASA on the investigation that—I believe that happened in October 2014——

Ms. WEXTON. Um-hum.

Mr. STALLMER [continuing]. To find—come to the accurate conclusion in the quickest amount of time, but going through a thorough investigation together, because I think you need the expertise from both parties. Congresswoman, if you wouldn't mind, as you brought up some of the issues that the ranges have, especially at Wallops, and on these East Coast ranges——

Ms. WEXTON. With the Chairwoman's indulgence, I don't mind at all.

Mr. STALLMER. Because I think it's rather pertinent what—some of the issues that the spaceports are dealing with is—and the launch industry's dealing with, Wallops, and down on the Cape, is the integration of our national air—the National Airspace System, the NAS, and this is a finite resource that we have, of the airspace. So whenever there's a space launch, we need to coordinate with the aviation community. And this has been a problem at Wallops in the past, which caused the delay of one of the launch vehicles, and——

Ms. WEXTON. I heard about it on the FAA side, too.

Mr. STALLMER. Yes. So that's one of the different committees—unpaid committees that I'm working on. That's one of the big issues that we are having, is working with the aviation community, and the launch community, on how we can effectively manage the National Airspace System. And thank you for being my Congresswoman.

Ms. WEXTON. You're very welcome, thanks. And with that, I'll yield back.

Chairwoman HORN. Thank you, Ms. Wexton. The Chair now recognizes Mr. Posey for 5 minutes.

Mr. POSEY. Well, thank you very much, Madam Chair, for holding this great meeting, and thank the panel for being here. I had to step away for a few minutes. Secretary Chao was announcing some grants that were approved, and one of them happened to be something we've worked on for a couple years, involved $90 million to access Kennedy Space Center. So, you know, if we can't get there, if the bridge collapses, we don't have a space center, so I had to step away for a few minutes, and, you know, in Florida alone,

the space industry impact totals $19 billion, 130,000 jobs in our State, so it's really big.

Space is important, but it's the commercial and civil space working together that really drives it, as most of you already know. Another driver is the *Space Resource Utilization Act*, which I introduced with Representative Kilmer in 2015, which is now law, and it allows for U.S. entities to retain the rights of resources they extract from celestial bodies, like asteroids, and it provides legal certainty for those who make significant investments to pursue space-based resources, like platinum, gold, and other high-value minerals. And I think of it much as you would have the California Gold Rush, except this is in space.

And I understand there was some discussion about that, as to whether or not this legislation had any property rights claiming in it. And let me assure absolutely, positively, unequivocally, beyond any shadow of doubt it did not. It refers only to resources, and so, you know, we don't lay claim to any celestial bodies because of that particular legislation, and let's just clear the air. Think that should be understood by everyone.

Ms. Montgomery, in your testimony, you said that the *Space Resource Exploration and Utilization Act of 2015* resolved one half of the uncertainty by recognizing private claims to extract the resources. And would you say that this, then, has helped developed the commercial industry to what we see today?

Ms. MONTGOMERY. I would say it has been very helpful.

Mr. POSEY. Great.

Ms. MONTGOMERY. So——

Mr. POSEY. You can pontificate longer, if you'd like.

Ms. MONTGOMERY. OK. All right. I will. No, I think that it has helped to put to rest a lot of uncertainty that the private sector felt about whether it could legitimately claim rights in the resources it worked to get. So, you know, the Moon Treaty is out there. The United States hasn't signed it, but it confuses people, and the ban on national appropriation also confuses people, so I think that what Congress did in 2015 really cleared the air. It was helpful.

Mr. POSEY. Yes. We, you know, we hear from some great panelists on this Committee. I mean, I think this is the greatest committee in the world, and here's some great, interesting, learned people, and we were told one time they think they've identified an asteroid with more platinum-based deposits on it than have been mined from the history on Earth during the entire history of man.

Ms. MONTGOMERY. Wow.

Mr. POSEY. I mean, that's a lot, and, you know, we know the environmental damage this mining does, and we know if we can pluck this stuff off an asteroid, you know, it's so much better for everybody. You know, win/win/win/win situation. Mr. Stallmer, would you say the law has helped develop the commercial space industry in what we're seeing today?

Mr. STALLMER. Yes. Just—and I'll elaborate. I think your leadership, and working with Congressman Kilmer, was really breakthrough in space resources, and how we pursue that, and I really think the long-term impact of that type of legislation, we won't really see the benefits until years to come, but I think it was very

foresightful on that legislation, so I think it will have a huge impact on the commercial industry.

Mr. POSEY. Yes. I remember hearing Neil DeGrasse Tyson, when we had him as a witness one time, he lectured in the Jefferson Building, and he said, you know, space is the only thing that we really spend money on, that Congress spends money on, that doesn't benefit us here today, that's really in the best interest of future generations. Like planting trees, the shade from which you never expect to enjoy the shade. And I think that's great, and I hope that helps energize and helps interest more of our young people. Got 33 seconds left, if anybody wants to weigh in on that.

Dr. LAL. We wrote a report recently, at NASA's request, on asteroid mining, and step zero is knowing what the potential of asteroids is, but then the steps one through seven, you know, you—from prospecting to going—getting to the asteroid, to mining it, to bringing things back, and there's a cost associated with each. And the tradeoff that needs to be done is how much would it cost to get there and bring the material back, and if that number is a positive number. So that's something to think about.

Mr. POSEY. Thank you. Time has expired.

Chairwoman HORN. Thank you very much, Mr. Posey. I agree, I think this is the greatest committee. Not only do we have space for fun, Mr. Weber, but we're doing important work, and raising important questions. So the Chair now recognizes Mr. Weber for 5 minutes.

Mr. WEBER. Thank you, ma'am. Thank you for your indulgence in letting me participate. Ms. Montgomery, I'm a little bit fascinated by your testimony on space law. How long have you been kind of in space law?

Ms. MONTGOMERY. Going on 30 years. I was in private practice, and did some satellite work, and then about 25 years ago I joined the FAA, where I spent 22 years doing space law.

Mr. WEBER. OK. And I notice——

Ms. MONTGOMERY. Rockets.

Mr. WEBER [continuing]. You talked about in 1967, there were signatories to the treaty, and, of course, that would've been under Nixon, and you said it was ratified by the Senate, I believe?

Ms. MONTGOMERY. Yes. Yes, it was.

Mr. WEBER. OK. And you weren't even in elementary school at that point, so I'm fascinated by your learned——

Ms. MONTGOMERY. Sir, I was in elementary school.

Mr. WEBER. Work with me here, I'm trying to help you.

Ms. MONTGOMERY. But I have to be truthful.

Mr. WEBER. Well, I appreciate that, as any good counselor would.

Ms. MONTGOMERY. Um-hum.

Mr. WEBER. And I'm reading about the case, where you're talking about what kind of law would govern this. And the reason I'm saying that is because we're going to talk about some SpaceX stuff, and their failure. And you cite the case Medellin vs. Texas from 2008, which I'm thoroughly familiar with, because it was a Mexican national that raped and killed two girls, and was sentenced to death, and I was going in as a State legislator and nominee and was following that very closely. And you talked about the ruling, where they said that those kinds of treaties, because the Mexican

government sued, of course, wanted to make sure that his rights were violated, he didn't get notified that he had the right to contact his embassy, you know the case.

Ms. MONTGOMERY. Um-hum.

Mr. WEBER. So, anyway, I'm kind of fascinated that you say that that might apply to space treaties. Go ahead.

Ms. MONTGOMERY. Yes, I would say it does, because in the law you can have principles that will apply across industries, or situations, if—even though they're all very different. So although the treaty was ratified, that is different from whether it is self-executing or not. And so when the Supreme Court talked about the treaty at issue in the Medellin case——

Mr. WEBER. Right.

Ms. MONTGOMERY [continuing]. It articulated the principle that if a treaty has been signed onto and ratified, but the entity in the U.S. Government that it obligates is the U.S. Congress, then everyone has to wait for the U.S. Congress——

Mr. WEBER. To act.

Ms. MONTGOMERY [continuing]. To act——

Mr. WEBER. Yes. That's right.

Ms. MONTGOMERY [continuing]. By passing a law.

Mr. WEBER. Right. And I agreed with that opinion, by the way, just for the record.

Ms. MONTGOMERY. Um-hum.

Mr. WEBER. But I want to fast forward. How many other attorneys are there and you may not know this, where do they teach space law? I notice you're from what college?

Ms. MONTGOMERY. I teach at Catholic University's Columbus School of——

Mr. WEBER. OK.

Ms. MONTGOMERY [continuing]. Law. There is also, sorry Representative Brooks isn't here, Ole Miss——

Mr. WEBER. OK.

Ms. MONTGOMERY [continuing]. Has a space law course. Nebraska has a space law curriculum. And then Georgetown and GW also have space law classes. American University, space law classes.

Mr. WEBER. Right.

Ms. MONTGOMERY. And McGill in Canada.

Mr. WEBER. My fear is that we don't want those international, indeed extraterrestrial, if you will, treaties being applied down in the various and sundry states, and hampering what commercial space exploration could do. And I'm thinking about, is there a move to take that law, and to hold countries and states accountable? Have you seen that at all?

Ms. MONTGOMERY. Yes, sir. When Moon Express went to the FAA for a payload review, the FAA did grant it, but it said, in its press release, that—we are concerned that they're not going to be regulated, and it's good they're only there for 2 weeks, otherwise, under Article 6, we would perhaps have had to say no. And I would say that that is contrary to the Supreme Court's articulation of how——

Mr. WEBER. And you noted in one of your footnotes that one of the Administrations took a different view of Article 6, one of the preclusions. Was that the Obama Administration?

Ms. MONTGOMERY. Yes, sir.

Mr. WEBER. OK. That's what I gathered by the date. Let me move forward here. I'm deeply concerned about the secrecy surrounding the launch pad explosion that destroyed SpaceX's Dragon capsule. Are you all familiar with that? I'm not getting all head shakes. OK. As you know, there was an unmanned test at Cape Canaveral, and it was recently revealed that a critical parachute failure occurred during the Dragon test capsule in April. You all are all aware of that? No? I'm not getting all head shakes. OK. This was kept secret from the public.

So this mishap is especially distressing, given that NASA's Aerospace Safety Advisory Panel specifically directed that parachute designs be finalized and proven before test flights occur. Back to the counselor. Ms. Montgomery, this should be governed by State law, Federal law? Does it fall under the purview of the Space Treaty? What say you?

Ms. MONTGOMERY. It is governed by the FAA regulation—the *Commercial Space Launch Act* and the FAA regulations, in terms of—I'm not really that familiar with the incident, but was it for a commercial crew, or was——

Mr. WEBER. It was unmanned, but yes, it was for a commercial crew.

Ms. MONTGOMERY. OK. So, as you may be aware, Congress told the FAA that it could not regulate for the safety of persons on board until 2023, that the industry is supposed to have the same sort of barnstorming era that the aviation industry got in the early days, so that—the FAA may be hampered in its ability to look at that, I don't know. But I stress that I don't know because I don't——

Mr. WEBER. Well, I know Mr. Stallmer made a comment in his remarks that the FAA had only gone halfway toward regulations, I believe you said? Hadn't gone far enough? And I just want us to be careful to know who's going to be controlling, who's going to be regulating, and what law governs. You have a comment? Madam Chair, if you'll indulge me? Mr. Stallmer?

Chairwoman HORN. Yes.

Mr. STALLMER. I—what I was referring to was—the halfway as in this current NPRM on some of the regulatory——

Mr. WEBER. OK.

Mr. STALLMER [continuing]. And the streamlining.

Mr. WEBER. OK. I got you. Thank you, and I appreciate your indulgence.

Chairwoman HORN. Thank——

Mr. WEBER. I'll yield back.

Chairwoman HORN. Thank you, Mr. Weber, and thank you for raising, I think, some very important questions. And thank you to our panel. If it wasn't clear before we started, there are a lot of issues that face us about commercial space, what exactly that is, Dr. Lal, to your point, how we classify it, how we quantify it, how we set the stage to encourage growth, but also provide accountability and certainty moving forward, and address the need for a

legal framework, where one doesn't necessarily exist in the regulatory environment, in order to make all of these things possible.

Taking this away, we clearly have a lot to look at moving forward. And I'll just sum it up with a few observations. There are a few buckets that I think we need to look at. One is what is the right level of oversight and investigation, and how we can—and transparency. I think, to your point, Mr. Weber, because that falls under a NASA contract, and how we look at that, the regulatory framework, and all of the things that are involved in that. And then what is commercial space? If 90 percent of a given program is a NASA program is funded by the government, at what point does that become commercial, and where do those issues enter in?

And the overall question is, where the markets have developed, and the places where they exist independently of a government customer. Again, going back, Dr. Lal, to your initial testimony that, despite innovation, the principal customer for many of these areas is still the government, which we see—how to set the regulatory framework, how to create the right balance, and how to properly define what is governmental, with private industry being a part of that, and what is truly commercial for the sake of commercial, and how we set the stage?

So clearly a lot of issues that we have to tackle moving forward, and sincerely appreciate your testimony, and your engagement today, as well as all of our Committee. I think this just goes back to the importance of the work that we're doing here, and I think a very clear bipartisan concern for doing the best we can to set this up to succeed in many ways. So thank you for being here today, thank you for your attention, your testimony, and—OK, wait, I've got to make sure I read the rest of the thing. Before we bring the hearing to a close, I want to thank our witnesses, and the record will remain open for 2 weeks for additional statements from the Members, and for any additional questions the Committee may ask of the witnesses. I would say be prepared, we may have additional questions. And the witnesses are excused, and this hearing is adjourned.

[Whereupon, at 3:52 p.m., the Subcommittee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Bhavya Lal

Responses to Questions for the Record

Commercial Space Landscape: Innovation, Market, and Policy

1. During the hearing, we heard many different definitions of "commercial space" in different contexts, and you offered several in your prepared testimony. In the context of NASA, what definition would you use to label a certain program or activity as "commercial" in nature, or not?

In my testimony, I spoke of three interpretations of commercial space: (1) companies that put angel or venture funding or their own resources at risk to build space systems (often, but not always, startups); (2) companies that serve or intend to serve a significant fraction of their customers outside the U.S. Government; and (3) purchasing approaches such as fixed-price contracts that are typically used in the broader market-based economy to purchase goods and services.

In the context of NASA, the third definition is the most relevant. A program or activity at NASA can be labeled "commercial" if it uses contracting mechanisms that require the performer to put "skin in the game." This could mean, for example, that the performer developed a particular product or service at their own risk, and NASA and other non-government users pay for its recurring use.

2. In response to my question during the question and answer session of the hearing, you stated that one of your top priorities for the Subcommittee on commercial space is looking at "alternative mechanisms of contracting" for small companies and/or start-ups, who may not have ability or background for the traditional contracts. What kind of alternative approaches should be considered?

In our 2019 report, *Assessment of the Utility of a Government Strategic Investment Fund for Space*, we examined almost two dozen economic policy instruments that could address the policy goals of the U.S. space program and foster the growth of a private space sector.[1] By juxtaposing these goals against the challenges companies face to address them, we found the following approaches could be the most useful:

- Increase the use of solution-based, fixed-price-type contracts that can reduce overhead and bureaucracy; contracts that use Space Act Agreements often fulfill these requirements
- Consider the use of advance purchase agreements or similar contracting mechanisms if NASA has need for a product that has already been developed
- Increase the use of in-kind subsidies, including subsidized access to space, and ground- and space-based testing facilities that will help companies demonstrate the performance and reliability of their products and services

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[1] K. Crane et al. *Assessment of the Utility of a Government Strategic Investment Fund for Space*. IDA Report. Science and Technology Policy Institute: Washington, DC. 2019. Available at https://www.ida.org/-/media/feature/publications/a/as/assessment-of-the-utility-of-a-government-strategic-investment-fund-for-space/d-10616.ashx?la=en&hash=A0E0F5DA11D73198284879A1600DCADC

- Increase the size, reduce compliance burdens, and accelerate timelines of R&D grants, contracts, and programs (such as SBIRs) targeted at smaller companies

Some experts have recommended mechanisms to encourage technology transfer from government agencies to startups by providing startup technology transfer packages that can reduce risks and improve attractiveness to venture investors.

Other members of the space community have suggested using prizes to spur the development of new technologies. We have found that prizes can work well for certain types of activities (such as algorithms or data analytics) where barriers to entry are low, required resources (such as a computer and internet access) are widely available, and solutions often depend on the ingenuity of solvers, including from outside the aerospace community. Prizes do not work well for problems that require expensive testing equipment, or where solutions depend on the development of costly hardware such as rockets and spacecraft for deep space.

3. Historically, the cost of launching to space has often been cited as one of the biggest barriers to entry into the space economy. Is that still the case?

Yes. In at least two recent studies in which we interviewed representatives of the private sector to identify challenges they face, we found that despite recent reductions, the price they pay for launch (and access to specific orbits of interest) remains a significant barrier to entry.[2]

Experts have proposed various alternative approaches to drastically reducing the cost of launch, including full reusability and advanced propulsion technologies; however, these savings have not yet been realized, and it is not clear when we will see the order of magnitude savings that have been postulated.

a. What are the biggest limitations or barriers right now for either new or existing companies to enter the space economy?

Through input from over 65 space industry experts, investors, government officials, and employees of start-ups, a recent STPI report (Crane et al, 2019) identified nine barriers, including cost of launch, faced by companies:

Goal	Challenge Faced by Private Companies
Reduce costs and accelerate development and procurement of systems for civil space exploration	Cost-plus contracting increases costs, lengthens development times, and reduces incentives to innovate on cost
	Requirements for 100% solutions can lead to the exclusion of lower cost "good enough" solutions
	Many contracting regulations make it difficult for non-traditional entities with innovative solutions to work with NASA

[2] B. Lal, et al. *Trends in Small Satellites and the Role of NASA Small Spacecraft Technology Program*. IDA Report. Science and Technology Policy Institute: Washington, DC. Available at https://www.nasa.gov/sites/default/files/atoms/files/nac_march2017_blal_ida_sstp_tagged.pdf

Goal	Challenge Faced by Private Companies
	Insufficient demand for products from specialized suppliers makes products unnecessarily expensive
Foster the growth of private space markets	Insufficient or unproven demand for products and services (especially those with longer timeframes) inhibits upfront private investment
	Lack of commonality between government and private market requirements makes products more expensive than needed
	High cost of testing and evaluation (as well as launch costs) prevents companies from bringing products to market, especially start-ups and smaller firms
	Government funding timelines are not aligned with private approaches, making government funds less useful
	Capital markets are failing to provide funding for promising ideas in space

Source: K. Crane et al. 2019.

4. You stated in your written testimony that there are areas where commercial capabilities now or will soon exceed those government capabilities, and while the commercial space industry can bring lower costs, "at times, this is at the expense of performance and reliability." Are there any sectors of the government's space efforts that you would have reservations about transitioning to commercial providers because of the needs in performance and/ reliability?

a. As commercial providers become the dominant or even only providers of certain services or capabilities, are there areas where the government needs to retain specific internal (i.e., inside the government) capabilities and skills indefinitely?

It is generally agreed that inherently governmental functions[3] (such as provision of national defense) should not be transitioned to commercial providers. The U.S. Air Force-operated Global Positioning System (GPS) may be a good example of an inherently governmental function in the space sector. No matter how much better a commercial satellite-based navigation system may get, or no matter how well a private party may operate GPS if it were to be privatized, the government should likely continue to own and operate the system given how much of our national security and economy depends on it.

[3] An inherently government function is defined in the Federal Activities Inventory Reform Act of 1988 (Public Law 105-270, Section 2(1)(A) as "a function that is so intimately related to the public interest as to require performance by Federal Government employees." Typically, inherently governmental functions require either value judgments for the Federal Government or discretion in applying Federal Government authority.

Apart from a very small number of national security related activities (such as GPS), almost all sub-sectors within space can, in principle, be transitioned to the private sector.[4] However, even sectors where private capabilities exceed those of the government (e.g., private space situational awareness (SSA) capabilities in GEO), the government needs to retain internal capabilities and skills such that: (1) it can objectively assess that private entities are proposing solutions that meet public needs; and (2) the solutions are priced such that those entities—not always driven by national interest—will not be overcharging taxpayers.

As more space-based activities are transitioned to the private sector, risk can be mitigated by regulating prices (as is done in other sectors such as the electric utility industry), legal provisions in the contracts, the ability to nationalize in times of war, the ability to purchase, and ensuring a multiplicity of providers.

I see three principal areas that can be used to identify areas where government's role (and therefore skills) needs to be significant. Note that these are not sub-sectors of space, but rather specific parts of the ecosystem.

- ***Funding Research.*** Private companies in free markets have no incentive to invest more fully in low-technical readiness level research, technologies, or platforms where they cannot—for a variety of reasons related to risk, timeline of return, insufficient demand, and other factors—get a full return on their investment
- ***Identifying and Funding Disruptive innovation.*** (Most) established companies have little incentive to invest in creating paradigmatic shifts that could potentially disrupt their current, profitable business models
- ***Strategic planning.*** With perhaps a few exceptions, individual companies do not see the full complexity of the technology ecosystem, and are not in a position to (nor do they feel a responsibility to) provide vision and strategic planning for that ecosystem, therefore leading to systematic coordination failures

5. Over the years, many private ventures with visionary space ideas have attracted significant attention for investors, the public, and the government in a way that is rarely seen in other industries. However, many of these promising new ventures never materialized. What should the government, the Congress specifically, be considering in balancing the desire to encourage or at least not discourage robust commercial space markets with the need to be realistic and responsible stewards of taxpayers' resources?

> **a. What information does the government need in order to achieve that balance when considering investing in early-stage ventures as a potential user or anchor tenant?**

Research has shown that disruptive ideas that move us from one technology platform to another typically come from outside the mainstream. It is therefore important for the space agencies to consider new ideas coming from commercial companies, universities, and other entities.

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[4] Here, it is important to make a distinction between *funding* a function versus *performing* a function. Just because the private sector can perform a function better does not mean the private sector can or will self-fund it. Conversely, just because the government should fund a function does not mean it should necessarily perform it as well.

However, separating the proverbial "wheat" from the "chaff" can be difficult, and there is no easy way to ensure stewardship of taxpayer funds. Some possible steps include:

- Use contracting approaches that ensure the private sector is taking risks together with the government (e.g., cost sharing on development when possible). Options include co-funding with larger corporations, for example, space-focused startup accelerators to provide critical early stage seed funding for startups
- Use approaches that lower barriers to greater private sector investment (e.g., advance purchase agreements when appropriate, regulations that lower risk of private investment, intellectual policy regimes that promote private investment)
- Take a page from the playbook of venture capital fund managers: 1) look for qualified teams that bring both technical and managerial expertise; (2) provide continuing mentoring support; and (3) pay attention to technological potential as well as sustainable and scalable business model development
- Ensure government review panels include a range of experts, including those who can ascertain, at the very least, that ideas are well-founded technologically (e.g., do not violate the laws of physics)
- Ensure transparency of decision-making

Ultimately, the government needs to be willing to take risks, and accept that the future is unknowable, and there will be some failures. Part of what the government does, and what private entities cannot do, is make big bets, especially when the future is not clear. In the past, the government has made bets that panned out (e.g., autonomous vehicles), and others that did not (e.g., copper indium gallium selenide thin film solar cells). Taking a portfolio approach in which funding is appropriately distributed among low, medium, and high-risk projects can allow government support of sufficiently successful and innovative technologies. A recent STPI study has shown that there are many good models within governments that agencies such as NASA can emulate.[5]

6. What are the opportunities, challenges, and associated policy issues that Congress should consider around large commercial satellite constellations?

From a market perspective, one of the biggest challenges in the space sector is that about half the demand for space-based products and services comes from the government. If services from satellite constellations (e.g., broadband or narrowband internet/telephony, imagery, or other space-based situational services such as collecting weather data, radiofrequency detection, among others) come to fruition, and companies operating constellations become profitable, it will open up the space sector to a much larger customer base.

This shift (from government as the only customer, to government as one of many customers) will transform parts of the space sector—that benefit from these constellation-based approaches—into more dynamic sources of innovation. For example, such an evolution could lead to changes

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[5] V. Pena et al *Early Stage Research and Technology in US Federal Government Agencies*. IDA Report 2017. Available at https://www.ida.org/-/media/feature/publications/e/ea/early-stage-research-and-technology-at-us-federal-government-agencies/d-8481.ashx

in design and manufacturing processes that produce satellites that are less expensive and more capable, and in turn, accelerate economic development.[6]

A key concern is that, while not all proposed constellations are likely to succeed, even the success of a small number will introduce an increased threat of collisions in space.[7] This is because many of the satellites will be small and emit no identifying beacons, and thus they cannot be tracked well; and many satellites will not have on-board propulsion systems, so it will be difficult for them to maneuver out of the way of other objects to avoid a collision. It is also likely that satellites in large constellations will stay in orbit well past their operational lives, and therefore create potential for future collisions unless effective deorbiting rules are imposed. Compounding these issues, our current satellite tracking systems are poorly suited to the growing space traffic and already generate false alarms and warnings that are not actionable.[8] This challenge will worsen as the number of spacecraft in orbit grows, and the number of conjunction warnings grow with it.[9]

These challenges also bring opportunities—in the form of more economic activity—through development and use of technology-based tools such as automated collision avoidance systems, onboard de-orbit systems, commercial ground- and space-based SSA systems, and active removal technologies. American companies are poised to offer these services to companies operating constellations and to the government.

The U.S. government could consider policy and regulatory approaches that might mitigate these effects. For example, operators could be required to enhance the trackability of their systems; develop best practices (including for data sharing) for maneuvering and collision avoidance; and de-orbit non-functioning satellites. Through government funding, the generation and sharing of SSA data could be improved such that conjunction warnings have fewer errors, and are more actionable.

7. What led to the successes of the significant revenue-generating markets in satellite services-such as television or location and timing services-and what lessons might we learn from those successes?

What led to the success of significant revenue generating markets from space was the creation of services (e.g., satellite TV, banking transactions, and applications such as Uber that use location services) for which a large number of households and businesses outside the government were willing to pay. The principal lesson here is that for a space sub-sector to create large markets, it has to offer something that entities *outside the government* want to buy.

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[6] Constellations provide many opportunities related to national security, space science, and global development, not covered above. There is a vast literature that describes these opportunities.

[7] It is important to note that space is big (volume of space to the GEO belt is 70 million million cubic miles; in contrast the oceans have a volume of only 400 million cubic miles); it is unclear how real congestion concerns are without a formal assessment.

[8] The current SSA system leads to an extremely high rate of false alarms: on the order of 99.99 percent (http://www.unoosa.org/res/oosadoc/data/documents/2019/aac_105c_12019crp/aac_105c_12019crp_7_0_html/AC105_C1_2019_CRP07E.pdf).

[9] If all the mega-constellations launched, current tracking technologies would generate over 67,000 "collision alerts" annually (https://aerospace.org/sites/default/files/2018-05/SpaceTrafficMgmt_0.pdf).

At present, beyond communications, geolocation and certain specialized Earth imaging applications, there are not many space-based products or services of interest to households and businesses. Until that occurs, space will remain a niche government-funded activity, limiting both the resources available to support technology endeavors and the variety and expanse of the technologies themselves. Some advocates believe asteroid-derived products (such as platinum group metals), other valuable materials on the Moon (such as Helium-3 that is expensive to produce on Earth and could be used to power fusion reactors on Earth), or other space-based activities (such as the generation of solar power in low Earth orbit to beam back to Earth) are illustrative of such future products. Other than asteroid mining (for which STPI did an analysis, see response to Q9), there is currently a lack of independent analyses of these areas to inform judgments about market potential.

Many space-based services grew as a result of large government investments over decades. Location based services came from an exclusively military-funded satellite-based navigation system (GPS). When it was initially deployed, no commercial applications were predicted (as was the case when the government invested in the early years of the internet). Similarly, communication satellites emerged from government-driven monopolies. Other benefits emerged from the government being an anchor tenant for a sector (e.g., space-based imagery). All these examples illustrate that sometimes future benefits of emerging technologies cannot be predicted, and the government may need to fund what it believes to be in the national interest without regard to commercial relevance.

a. Are there emerging markets in the commercial space industry now that have the potential to deliver the same level of economic impact?

We know of no rigorous systematic research on which emerging markets might have the same level of economic impact as satellite TV (apart from space-based broadband internet). There are many ideas (including, as noted above, asteroid mining, space-based solar power, mining Helium-3 on the Moon) that come from space enthusiasts, but given the lack of objective analyses, it is not clear that these ideas are practical or cost effective, let alone able to deliver significant economic impact. If these activities are to be pursued, they need to be preceded by independent analyses of the technologies and economics.

8. The National Space Policy states that the U.S. Government should not "discourage or compete with the U.S. commercial space activities." How would you assess whether or not the government is competing with or discouraging commercial space activities that are still in planning phases, have not yet been fully demonstrated, and/or are reliant on the government as the sole customer?

To assess whether a space capability already exists in the private sector, there are questions the government can pose (for example, through Requests for Information, or through surveys of the sector) to learn more about the presence and maturity of commercial capabilities, and ensure that the government does not discourage or compete with the commercial efforts.

The assessment needs to be solutions-based rather than process or technology-based. Using launch as an illustration, if the goal is to deliver x metric tons of cargo on the Moon, instead of looking for a launcher with a specific thrust or payload capacity, the government should look for

total cost of delivery (even if there may be need for multiple smaller vehicles to make the delivery).

To assess whether a capability can be commercially developed in the future (as was the case for commercial launch through the COTS program), as distinct from whether it already exists, is significantly more complicated. Trial and error, similar to the current assessment of commercial capabilities for the Moon, may be the best way to proceed. The decision may come down to whether the government wishes the private sector to develop a certain capability to serve customers outside the U.S. Government en route to a larger space economy,

9. During the question and answer session of the hearing, you mentioned that the Science and Technology Institute (STPI) had recently prepared a report on asteroid mining at NASA's request. What were the main conclusions of the report?

From September–November 2018, the IDA Science and Technology Policy Institute (STPI), under contract NSFOIA-0408601, Project ED-20-4199, conducted a study entitled *Utilization of Asteroid-Based Natural Resources*, for the National Aeronautics and Space Administration. The report may be obtained from NASA. The key findings are summarized below:

- We identified approximately 30 U.S.-based companies that could be considered part of the aspirational asteroid resource extraction ecosystem. Not all can be considered commercial in that not all have private risk capital, or have firm plans to serve non-government customers in addition to government ones. Of the three companies explicitly billed as focusing on asteroid mining, two have recently folded, and the one that remains is largely government-funded with a small number of employees. From these failures, it would be reasonable to assess that the first round of commercial space mining has ended. To be fair, while these companies may not have achieved their principal goals, they did create awareness in the public and policymaker community regarding the economic potential of asteroid mining, and even led to laws governing space-based resource extraction.
- In the near-term, the economic viability of asteroid resources for space missions will be driven by three major factors: cost of launching those same resources from Earth; cost of the mining and in-space processing infrastructure; and total demand for the in-space resources over which the infrastructure cost will be spread.
- We found no commercial case for mining resources on asteroids, like platinum, and bringing them back for sale on Earth. Demand for resources extracted in space likely will be confined to water or possibly methane, resources that could be potentially used for propulsion. At least through the 2040s, this demand will likely come from government customers, and will depend on the architectures selected.
- To reduce technology and market uncertainties, research efforts need to first focus on prospecting, in particular, evaluating the resource potential of specific asteroids. Missions to explore the distribution and composition of asteroids are necessary to determine whether they truly are a potential source of water and other resources.
- Private markets, and especially venture capital firms, seek returns within 7–10 years; given the timeline over which use of asteroid-based resources is likely viable—a decade or longer—and the uncertainty of returns, it is unrealistic to expect private markets to fund the development of these technologies.

- Given the lack of a near-term commercial payoff, government funding may be the only option for this activity. Government funding to test the various systems that would be involved in mining and more detailed analysis of the potential for asteroid-propellant-fueled space tugs could be useful steps to investigate whether asteroid mining of propellants could be economically viable.
- At this time, asteroid mining-related activity is better supported through either research grants or other forms of government R&D support, especially innovative public-private approaches similar to the one used to develop options for cargo delivery to the International Space Station. Some experts have suggested the government use advance purchase agreements (in other words, set a price at a future date at which it will purchase propellant) to spur innovation, especially from entrepreneurial commercial firms. However, this is possible only if future prices can be rationally set. Regardless of the approach used, in the near-term, the government has an important role to play in creating the knowledge and infrastructure to develop and utilize space-based resource extraction.
- Our overall assessment is that while asteroid mining may be a critical component of long-term sustained human presence in deep space in a future in which the solar system might be brought into Earth's economic sphere, today it is at best a nascent, highly speculative activity.

10. Does the U.S. have in place the elements of a sustained, skilled workforce that can help ensure the growth and leadership of our U.S. commercial space industry?

In 2015, the latest year for which NSF data are available, students earned 650,000 science and engineering (S&E) bachelor's degrees at U.S. institutions of higher Education (100,000 engineering degrees)—up nearly 25 percent from 2010 for all S&E degrees. The number of aerospace engineers increased 20 percent between 2010 and 2015.[10] There are no signs that the number of S&E workers to help grow and support the commercial aerospace industry is currently insufficient. A proper workforce demand study would need to be conducted to make this conclusion definitively.[11]

a. If not, what needs to be done to ensure the necessary workforce and skills are available to support the U.S. commercial space industry?

In addition to encouraging enrollments in fields related to the aerospace industry, retraining programs for those with basic skills (not just S&E-related skills, but also business and marketing skills) is a mechanism to consider. Building two-year skilled technical workforce programs for jobs that do not require a bachelor's degree education could be built up. Apprenticeships, cooperative education programs with commitments of training by the commercial space sector, could be considered. The government could contribute to the training of this workforce, but the private sector should also commit to investing in training opportunities.

b. To what extent would the lack of skilled employees impede the growth of the U.S. commercial space industry?

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[10] S&E Indicators 2018: https://www.nsf.gov/statistics/2018/nsb20181/data/appendix - appendix table 2-21

[11] The response to question 10 was written with support from STPI researcher Dr. Asha Balakrishnan.

A skilled workforce is essential for the growth of an industry, and lack of skilled employees will certainly impede the growth of the commercial space sector. However, it is not clear that the U.S. commercial space industry is suffering from the lack of a trained workforce.

Responses by Ms. Carissa Christensen

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE AND AERONAUTICS

The Commercial Space Landscape: Innovation, Market, and Policy

Questions for the Record to:

Ms. Carissa Christensen

Submitted by Chairwoman Horn

1. During the hearing, we heard many different definitions of "commercial space" in different contexts. In the context of NASA, how would you distinguish a given program or activity as being "commercial" in nature, or not?

   It is appropriate that there are many different definitions of commercial space; the relevant definition of commercial space depends on the context of the discussion. For policy discussions, where the government seeks to leverage commercial business model innovation, the degree of government involvement in a market place is an important consideration, as reflected in National Space Policy. When evaluating the financial position of businesses, the source of revenue is less important, generally, than the volume and stability of revenue.

2. What led to the successes of the significant revenue-generating markets in satellite services-such as television or location and timing services-and what lessons might we learn from those successes?

   The key to success for these significant revenue-generating markets in satellite services has been delivering value-added services that are either competitive in quality and price with terrestrial alternatives (as is the case with direct to home television) or delivering services that are not replicable with terrestrial capabilities (as is the case with location and timing services).

   a. Are there emerging markets in the commercial space industry now that have the potential to deliver the same level of economic impact?

      There is the potential for significant demand across multiple areas, including, for example, mobile telecom services, satellite broadband, value added services using satellite imagery, and perhaps suborbital tourism.

   b. What is needed to facilitate those emerging markets in realizing a larger-scale economic impact?

      The key to market growth in emerging markets will be demonstrating the ability to achieve price points that attract mass market customers.

3. Historically, the cost of launching to space has often been cited as one of the biggest

barriers to entry into the space economy. Is that still the case?

a. What are the biggest limitations or barriers right now for either new or existing companies to enter the space economy, and what is needed to address those barriers?

For the satellite industry as it is currently constituted, the cost of launch is not a significant barrier to growth. The cost of launch is a significant factor for markets requiring human access to space and associated systems. Currently, many of the biggest barriers to growth involve demonstrating the ability to produce viable products that are competitive on price and quality in existing markets. NASA, with the support of Congress, is taking important steps to help the industry address and overcome these barriers with policies, such as the ISS Commercial Utilization policy, and investments such as those made in the NextSTEP and ISS National Lab programs.

4. What are the opportunities, challenges, and associated policy issues that Congress should consider around large commercial satellite constellations?

Two important areas for Congress to consider regarding large commercial satellite constellations are methods to protect relevant spectrum for satellite usage and the potential need for legislation regarding space debris management and removal.

a. Can large commercial satellite constellations replace legacy satellite services, such as TV and radio, that generate a significant portion of the commercial space market revenue today?

It is unlikely that large commercial satellite constellations in a low Earth orbit would replace legacy satellite services in applications where the physics of placing fewer large satellites in more distant geosynchronous orbit results in highly efficient point to multipoint capabilities. Television has historically benefitted from this attribute. Large constellations in low Earth orbit can augment legacy capabilities, especially in areas where having satellites closer to Earth could enable broadband and mobile services with very low latency.

5. The National Space Policy states that the U.S. government should not "discourage or compete with U.S. commercial space activities." How would you assess whether or not the government is competing with or discouraging commercial space activities that are still in planning phases, have not yet been fully demonstrated, and/or are reliant on the government as the sole customer?

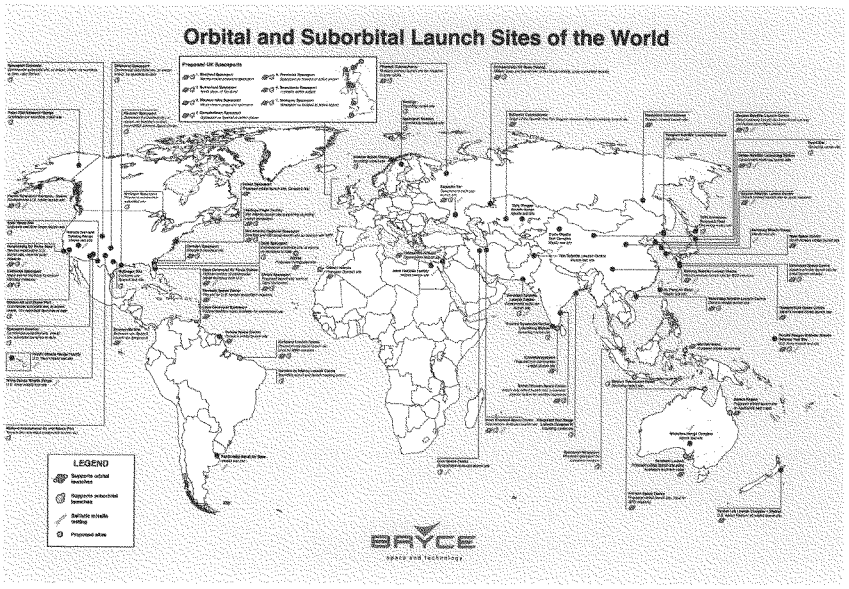
The government must evaluate prospective commercial providers' ability to support the government's required mission capability. In some cases, the government is actively engaged in these evaluations. In the past few years the National Geospatial Agency, National Reconnaissance Office, Department of Defense, NASA and the National Oceanic and Atmospheric Administration, to name a few agencies, have all undertaken pilot programs to evaluate commercially provided capabilities. In some cases, the government will find, or has already found, that due to operational

requirements it can only rely on a government owned system. To some extent, this is likely to always be the case. In other cases, however, I expect that as agencies get better at identifying and managing uncertainty related to new start-up ventures, they will find more opportunities to leverage and partner with industry.

6. During the question and answer portion of the hearing, in response to a question about launches from spaceports by Representative Wexton, you noted that we are seeing growth in the foreseeable future. You also indicated that spaceports can better prepare for anticipated launch demands by engaging with small satellite operators. Are there any projections for the number of future small-satellite launches that are anticipated to be carried out at spaceports in the short- and long-term future? If so, what are they?

   The number of small satellite launches in the short- and long-term will mainly depend on the commercial success of proposed large smallsat constellations. If a few of these systems succeeds, Bryce anticipates there could be more than 8,000 satellites launched in the 2020s. If no large smallsat constellation succeeds, we expect that number to be closer to 1,500; while if multiple constellations succeed the number could be as high as 15,000.

   Spaceports will face global competition, from a growing number of spaceports, to capture these launch revenues (see map).



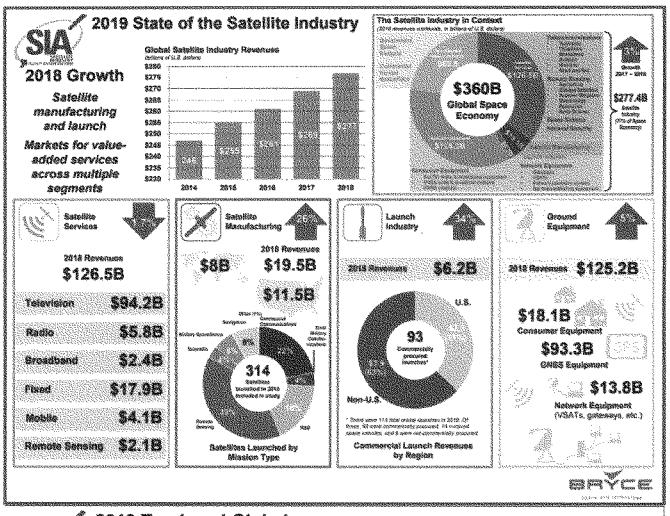
7. Over the years, many private ventures with visionary space ideas have attracted significant attention from investors, the public, and the government in a way that is rarely seen in other industries. However, many of these promising new ventures never materialized. What should the government, and Congress specifically, be considering in balancing the desire to encourage--or at least not discourage-- robust commercial space market with the need to be realistic and responsible stewards of taxpayer resources?
    a. What information does the government need in order to achieve that balance when considering investing in early-stage ventures as a potential user or anchor tenant?

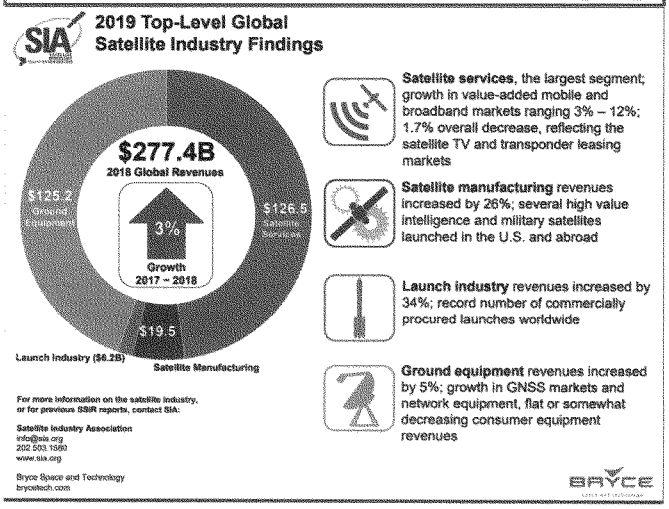
The government is a long standing customer of commercial space capabilities and has helped facilitate today's commercial space markets. The government has an opportunity to leverage emerging commercial space companies, but the price of leveraging this investor-funded, dynamic innovation is uncertainty. The government must carefully consider how to best take advantage of this opportunity, while ensuring long-term access to mission critical services. The government should consider this uncertainty in acquiring products and services and establishing regulations. The government will be well served by being a flexible and informed customer and partner with industry. Implementing acquisition processes and partnering mechanisms that recognize and specifically address this business uncertainty will help the government benefit while managing risk.

8. Assessments and projections of trends in commercial space markets and the various sectors is important to understand. Are there any independent market assessments and forecasts for the commercial space industry released/updated regularly?
    a. What role, if any, should the federal government have in gathering, reporting, and/or assessing commercial space markets and making them available to the public?

Aside from government forecasts, there are multiple companies that develop forecasts for the commercial space industry. Generally, the most reliable forecasts are considered to be highly-proprietary and are not publicly released.

The Satellite Industry Association, supported by Bryce, issues an annual historical "State of the Satellite Industry" report, which is a 20-year time series of data about current trends in the space industry built off industry surveys. The executive summary of this report is included below.





9. Does the U.S. have in place the elements of a sustained, skilled workforce that can help ensure the growth and leadership of our U.S. commercial space industry?
   a. If not, what needs to be done to ensure the necessary workforce and skills are available to support the U.S. commercial space industry?
   b. To what extent would the lack of skilled employees impede the growth of the U.S. commercial space industry?

There are some isolated skill areas where workforce weaknesses affect the space industry,

but workforce limitations are not generally a primary concern for emerging space companies. The workforce skills that the space industry seeks—analytics, artificial intelligence, machine learning, robotics, to name a few—are also sought and developed by other industries, helping to incentivize development in these workforce areas. While workforce is not currently a primary concern for the space industry, it is important that the U.S. continues to train its workforce in relevant technology areas to ensure this does not become a limit of future space industry activities.

Responses by Mr. Eric Stallmer

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE AND AERONAUTICS

The Commercial Space Landscape: Innovation, Market, and Policy

Questions for the Record to:

Mr. Eric Stallmer

Submitted by Chairwoman Horn

1. **During the hearing, we heard many different definitions of "commercial space" in different contexts. In the context of NASA, how would you distinguish a given program or activity as being "commercial" in nature or not?**

I would distinguish a given program or activity as being commercial in nature if it both meets the following definition of a commercial activity, and it embodies the characteristics of a commercial activity.

1) In general, the term "commercial" refers to space goods, services, or activities provided by private sector enterprises that bear a significant portion of the investment risk and responsibility for the activity[1], operate in accordance with typical market-based incentives for controlling cost and optimizing return on investment, and have the legal capacity to offer these goods or services to existing or potential nongovernmental customers.[2]

In addition to this general definition, there are additional characteristics to a NASA acquisition contract that are indicative of a commercial activity. These include, but are not limited to, contracts or agreements that:

- *Establish clear, high-level, milestone-based requirements that enable creative, innovative, and cost-effective solutions and avoid overly-specified and ever-changing Government requirements. This structure forces the Government customer to get the requirements right and clearly communicate priorities at program start. A healthy alignment of incentives strengthens a project at its start by encouraging early*

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[11] From Title 51—NATIONAL AND COMMERCIAL SPACE PROGRAMS. Subtitle V—Programs Targeting Commercial Opportunities. 50501. Definitions. (3) Commercial.—The term "commercial" means having—
(A) private capital at risk; and (B) primary financial and management responsibility for the activity reside with the private sector.

[2] From National Space Policy. Available at:
https://obamawhitehouse.archives.gov/sites/default/files/national_space_policy_6-28-10.pdf

decision making that focuses on future operational results like unit costs, reliability, maintainability or safety. Inversely, a poor incentive structure encourages short-term thinking that makes future results and operational considerations an afterthought, leading to systems that are ever more expensive to fly that only the government can afford.[3]

- *Use of firm, fixed-priced, pay-for-performance, milestone-based agreements that drive toward a successful conclusion and for on an outcome-oriented commercial service. This commercial structure incentivizes companies to provide the deliverable at the time, place, and price negotiated with the Government, and discourages continuous Government requirement changes that add costs and delay schedule. The GAO reports, "Performance-based acquisition (PBA) is, as the Panel reported in 2007, a preferred commercial technique. PBA focuses on contractors' deliverables rather than how they perform the work. Rather than using traditional statements of work that define requirements in great detail, PBA uses performance work statements (PWS) that define Requirements more generally based on desired outcomes."*[4]
- *Maximize competition throughout the entirety of the program. Competition is critical to accelerating progress, driving value and performance, and improving the quality of service to the customer. Price competition obviates the need to levy expensive, anti-competitive, non-value added requirements for certified cost or pricing data. Here the GAO reports, "Competition is considered the cornerstone of a sound acquisition process and a critical tool for the government. It helps agencies achieve the best prices and return on investment for taxpayers."*[5]
- *Require a significant private capital contribution to the overall program. Commercial partners should share costs and provide a significant percentage of the overall investment, resulting in lower costs to the Government and enabling it to stretch its budget further. This also provides high incentivizes for commercial firms to drive toward operational success to generate revenue and recoup their investment. The contractual nature of commercial activities are such that cost overruns are unlikely to mean more cost to NASA. Reduced cost risk to NASA goes with the notion that partners have "skin in the game" and will try to control costs better when they are also investing their own private capital or trying to develop a system that will be affordable to others outside of NASA. The potential for private sector customers*

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[3] Edgar Zapata, "An Assessment of Cost Improvements in the NASA COTS/CRS Program and Implications for Future NASA Missions." June 2017. Available at: https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170008895.pdf
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[4] Government Accountability Office, "*Federal Acquisitions: Congress and the Executive Branch Have Taken Steps to address Key Issues, but Challenges Endure,*" September 2018, (GAO-18-627). Available at: https://www.gao.gov/assets/700/694457.pdf

[5] Ibid. page 16.

encourages operational affordability and reliability in a way that mere NASA operational guidance never could.[6]

- *Tolerate programmatic risk and allow easy termination for failure to meet early requirements. The Government needs the flexibility to terminate contracts and cut bad actors when programs go far over budget and behind schedule.*
- *Facilitate the development of new markets and leverage market-driven pricing to support Government requirements and missions. Investing to help partners mature their capabilities follows best practices whereby new product development decisions are delayed as long as possible, gathering practical knowledge along the way to establish each business case. This runs counter to non-commercial contracts which, even though involving many bidders, make this critical decision early (seeming decisive) and select one provider based only on the pile of bids.*[7]
- *Mirror commercial terms and conditions to the maximum extent. For example, a commercial contract for a service never takes ownership of hardware. The purchase is for the service, not the vehicle, stage, spacecraft, etc. providing the service. In contrast, a private sector entity providing. Commercial friendly intellectual, data and physical property rights.*
- *Eliminate all other FAR-derived provisions that are not essential to incentivizing the core outcome.*

To be clear, a private company or government program that does not fulfill these requirements does not meet the definition of "commercial space;" for example, the private companies working on the Space Launch System (SLS) are not "commercial space," and the SLS itself is inherently not commercial in any form. It would be disingenuous to confer the definition of commercial space to SLS in any form, even though private contractors are supporting it.

2. What is the proportion of private, nongovernment investment to government investment for the Commercial Orbital Transportation Services (COTS) and the Commercial Crew Program (CCP)/ Commercial Crew Transportation Capability CCtCap development projects?

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[6] Edgar Zapata, "An Assessment of Cost Improvements in the NASA COTS/CRS Program and Implications for Future NASA Missions." June 2017. Available at: https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170008895.pdf a

[7] Surat Gablin Gunasekara, "Other Transaction Authority: NASA's Dynamic Acquisition Instrument for the Commercialization of Manned Spaceflight or Cold War Relic?" January 2012. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1992483 .

Figure 3[8], below, shows the raw data for private investment in the Commercial Cargo effort, the partners themselves, and state entities. The total of NASA and other private or non-NASA investments in commercial cargo systems develop was $1.9 billion (in nominal dollars) of which 47% was government (NASA or state) funding. Therefore, a majority of the COTS investment came from the private sector.

There is no similar quantitative public data for private or other investments in the commercial crew program. NASA did require that proposals for providing commercial crew services tabulate their "life Cycle Cost Risk Assessment — Offeror Investment Contribution". Some private investments in Commercial Crew are substantial financial contributions.[9].

It is important to note that Commercial Crew provider SpaceX has significantly invested toward supporting the program, particularly with investments toward launch site development and launch vehicle reliability and performance improvements.

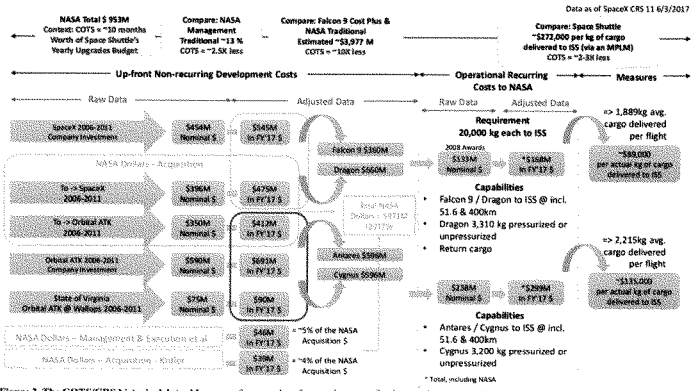

Figure 3. The COTS/CRS historical data. Measures of cost per kg of cargo shown are for the actual tonnage delivered, not the maximum the spacecraft or carriers are capable of hauling. The measure includes the cost to NASA for launch services where the launch failed, with zero payload delivered. As of SpaceX CRS-11, 6/3/2017.

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[8] Edgar Zapata, "An Assessment of Cost Improvements in the NASA COTS/CRS Program and Implications for Future NASA Missions." June 2017. Available at: https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170008895.pdf

[9] Edgar Zapata, "An Assessment of Cost Improvements in the NASA COTS/CRS Program and Implications for Future NASA Missions." June 2017. Available at: https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170008895.pdf

3. Do the proportions of private, nongovernment investments to government investments for COTS and CCP/CCtCap qualify as "commercial"? If so, why and who are the nongovernment customers?

Yes, and an emphatic yes! Both programs meet both the definition and the distinctive characteristics of what is a commercial program or activity that I outlined in the answer to your first question.

Here are a list of current nongovernment customers for the commercial crew and cargo programs:

- *1Drop Diagnostics, Inc*
- *A-76 Technologies, LLC*
- *ACME Advanced Materials*
- *Adcole Maryland Aerospace, LLC*
- *adidas International, Inc.*
- *AIRBUS DS Space Systems, Inc.*
- *Amplyus LLC*
- *AMSAT (Amateur Satellite Radio Corporation)*
- *Angiex, Inc*
- *Aphios Corporation*
- *Arizona State University*
- *Arthur C Clarke Center (UCSD)*
- *Astrileux Corporation*
- *Astrobotic Technology Inc.*
- *Auburn University*
- *Audacy Corporation*
- *Axiom Space, LLC*
- *AxoSim Technologies*
- *Battelle Oak Ridge National Lab*
- *Baylor College of Medicine*
- *Bell Middle School*
- *Benevolent Technologies for Health*
- *Beryllium Discovery Corp.*
- *Bigelow Space Operations, Inc.*
- *Biogen*
- *BioOptoSense, LLC*
- *Biorasis, Inc.*

- *BioServe Space Technologies*
- *Board of Regents of the University of Wisconsin System*
- *Boston University*
- *Boy Scouts of America*
- *Brigham and Women's Hospital*
- *Bristol Myers Squibb*
- *bSpace Corporation*
- *Budweiser*
- *California Institute of Technology*
- *Cam Med, LLC*
- *Case Western Reserve University*
- *Cellino Biotech, Inc.*
- *Cemsica*
- *Children's Hospital of Philadelphia*
- *City College of New York*
- *Clemson University*
- *Cobra Puma Golf*
- *Colgate-Palmolive*
- *Collins Middle School*
- *Controlled Dynamics Inc.*
- *Cornell University*
- *Craig Technologies Aerospace Solutions (CTAS)*
- *Cristo Rey Jesuit College Preparatory of Houston*
- *Deep Space Industries*
- *Delta Faucet*
- *DexMat, Inc.*
- *Dover Lifesciences*
- *Duchesne Academy of the Sacred Heart*
- *Durham Veterans Administration Medical Center*
- *Eclipse Energy Systems, Inc.*
- *Eli Lilly and Company*
- *Emory University*
- *Emulate, Inc.*
- *EnerLeap*
- *First the Seed Foundation*
- *Florida State University*
- *FOMS, Inc.*
- *Frederick National Laboratory for Cancer Research*
- *Georgia Institute of Technology*

- *GlaxoSmithKline*
- *Goodyear Tire & Rubber Co.*
- *Guardion Technologies*
- *Harris Corporation*
- *Hauptman Woodward Medical Research Institute, Inc.*
- *Hewlett Packard*
- *HNu Photonics, LLC*
- *Honeywell International*
- *Houston Methodist Research Institute*
- *HySpeed Computing*
- *Icahn School of Medicine at Mount Sinai*
- *Illinois Institute of Technology*
- *Indiana University*
- *Intuitive Machines*
- *Iowa State University*
- *iXpressGenes, Inc.*
- *JAMSS America, Inc.*
- *Juxtopia, LLC*
- *KBRwyle*
- *KBRwyle*
- *Kentucky Space, LLC*
- *Kernal Biologics*
- *LaMont Aerospace*
- *LaunchPad Medical*
- *Lockheed Martin Corporation*
- *Loma Linda University*
- *Louisiana State University Health Sciences Center*
- *Lovelace Respiratory Research Institute*
- *Lux Labs, Inc*
- *Made In Space*
- *Magnitude.io*
- *MakerHealth*
- *Marvel Entertainment*
- *Massachusetts Institute of Technology*
- *Mayo Clinic - Jacksonville*
- *Medimmune Inc*
- *Merck Pharmaceuticals*
- *Meredith Corporation*
- *Michael J. Fox Foundation*

- *Michigan Technological University*
- *Micro-gRx, Inc.*
- *MicroQuin*
- *Milliken*
- *Morehead State University*
- *Nalco Champion*
- *Nanobiosym*
- *NanoRacks, LLC*
- *National Cancer Institute*
- *National Ecological Observation Network*
- *National Jewish Health*
- *NCESSE/Tides Center*
- *NEMAK*
- *Neural Analytics*
- *New Jersey Institute of Technology*
- *Nickelodeon*
- *Northern California Institute for Research and Education*
- *Northwestern University*
- *Novartis Institute for Biomedical Research*
- *NovaWurks, Inc*
- *Novopyxis*
- *Oncolinx Pharmaceuticals LLC*
- *Optisys*
- *Orbital Sidekick*
- *Orions Quest*
- *Ozark Integrated Circuits, Inc.*
- *Palo Alto Veterans Research Institute*
- *Pheronym, Inc.*
- *Physical Optics Corporation*
- *Procter and Gamble Company*
- *Protein BioSolutions*
- *ProXopS, LLC*
- *Quad Technologies*
- *Radiation Monitoring Devices, Inc.*
- *Raja Systems*
- *Ras Labs LLC*
- *Regents of the University of Colorado*
- *Rensselaer Polytechnic Institute*
- *Rhodium Scientific*

- *Saint Louis University*
- *Sanofi Pasteur*
- *Schafer Corporation*
- *Scripps Research*
- *SEOPS, LLC*
- *Sierra Nevada Corporation*
- *Silverside Detectors*
- *Southwest Research Institute*
- *Space Science Institute*
- *Space Tango, Inc.*
- *Space Technology and Advanced Research Systems Inc. (STaARS)*
- *SQZ Biotechnologies*
- *Stanford University*
- *SyNRGE, LLC*
- *Talbot Innovation Middle School*
- *Technical Education Research Centers*
- *Techshot, Inc.*
- *Texas A&M Health Science Center*
- *The Awty International School*
- *The Boeing Company*
- *The Jackson Laboratory*
- *ThinkSpace Consulting*
- *Twin Cities PBS*
- *Tympanogen, LLC*
- *University of Alabama Birmingham*
- *University of Alaska Anchorage*
- *University of California, Los Angeles*
- *University of California, San Francisco*
- *University of Colorado Boulder*
- *University of Delaware*
- *University of Florida*
- *University of Houston*
- *University of Kansas Medical Center*
- *University of Maryland*
- *University of Maryland Baltimore County*
- *University of Miami*
- *University of Michigan*
- *University of Minnesota*
- *University of Notre Dame*

- *University of Pittsburgh*
- *University of Southern California*
- *University of Texas El Paso*
- *University of Toledo*
- *University of Washington*
- *Upstream Tech*
- *Virginia Commonwealth University*
- *Visidyne, Inc.*
- *Vision Engineering Solutions*
- *Voxa*
- *Yosemite Space*
- *Zaiput Flow Technologies*

- *Other customers include non traditional space countries interested in creating their own human spaceflight program buying seats on commercial vehicles.*
- *There is also significant interest for customers from private research institutes to do human-tended research on these platforms.*
- *NASA recently announced it would permit up to two commercial missions per year to ISS, and there has been significant industry interest in this capability.*

a. What is the proportion of private, nongovernment investment to government investment that you anticipate for NASA's low Earth orbit development program and for the lunar lander and Gateway elements of NASA's Moon program?

The private sector has invested billions of dollars of private, nongovernment capital in NASA's low Earth orbit development and lunar lander and Gateway elements of NASA's Moon program. Here are just a few examples:

- *SpaceX invested $454 million to meet Falcon 9 and Cargo Dragon initial capability and more than a billion additional dollars in upgrading both the Falcon 9 and Dragon vehicles to improve performance and reliability. In addition, SpaceX has invested at least $500 million in private investment development Falcon Heavy, which along with Falcon 9, will help resupply NASA's Gateway and Moon program. SpaceX has also invested significant private funds in its Starship.*
- *Blue Origin has invested billions of dollars to design, build, and operate the New Shepard vehicle, human capsule, and New Glenn for commercial LEO. In addition to*

New Glenn being able to provide logistics capability to cis-Lunar space, Blue has also invested significant capital in its BE-7 lunar lander engine and Blue Moon lunar lander.

- *NanoRacks has invested $40 million of private capital, and its investments continue to grow. Most recently NanoRacks made significant strides in building a new airlock to attach to the ISS, which will be the first permanent commercial structure on the ISS since its construction.*
- *Sierra Nevada Corporation has invested over a billion dollars in its Dream Chaser vehicle, which will provide cargo to and from the ISS and other commercial LEO destinations.*[10]
- *Bigelow Aerospace has invested hundreds of millions of dollars in its expandable habitats for both commercial LEO and Moon related activities.*
- *Maxar has invested tens of millions of dollars of private, nongovernment investment in its portion of the Gateway element of NASA's Moon program. For example, Maxar's power and propulsion element design is based on its powerful 1300-class platform. There are 91 spacecraft based on the 1300 currently on orbit for commercial operators – more than any other model of communications satellite.*[11]
- *On the capital access front, more than $150 million of funding from external, non-NASA sources is now invested in the full ISS National Lab project portfolio.*[12]

Historically, the cost of launching to space has often been cited as one of the biggest barriers to entry into the space economy. Is that still the case?

- *The commercial space industry's investment in reusability is dramatically reducing the cost of space access.*
- *The Falcon 9 and Falcon Heavy rockets routinely launch using flight-proven first stage boosters, and SpaceX has begun recovering the fairings used to shield satellites during launch. Together, these activities save millions of dollars per mission, and SpaceX has supported both NASA and US Air Force missions with flight-proven boosters.*
- *Blue Origin has also announced its intent to develop the reusable New Glenn launch system for orbital missions.*
- *The cost of launching small satellites has also reduced dramatically with the advent of rideshare missions on large launch vehicles and with small launch systems.*

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[10] https://spacenews.com/sierra-nevada-ready-to-complete-assembly-of-first-dream-chaser-spacecraft/

[11] http://investor.maxar.com/investor-news/press-release-details/2019/Maxar-Selected-to-Build-Fly-First-Element-of-NASAs-Lunar-Gateway/default.aspx

[12] https://www.issnationallab.org/blog/investment-perspectives-snapshots-from-the-iss-national-lab-fy18-annual-report/

- *This reduced cost of space access is offering both Government and private spacecraft developers significant new opportunities to launch payloads of all sizes to earth orbit and beyond.*

b. What are the biggest limitations or barriers right now for either new or existing companies to enter the space economy?

- *Government competition with commercial entities is a big barrier to entry. Whether it's distorting markets by giving away excess government assets, forcing commercial companies to use government facilities, or government capabilities competing against commercial capabilities to win private as well as government business, government creates a lethal barrier to entry to commercial companies entering into the space economy. This manifests in many ways and must be avoided.*
- *For example, the Government should not compete SLS against commercial launch vehicles for the delivery of payloads to the Moon under the Artemis Program. This approach undermines the commercial sector and ultimately dramatically increases costs to the taxpayer.*

Cumbersome regulations and authorization authorities:

- *Launch & Reentry regulatory reform: Today's increasing rates of launches and reentries, together with innovative operations and continued industry diversification, are bringing to light new non-technical challenges. The first of these is the obsolete, burdensome, and duplicative body of regulations for launch and reentry. Today's rules were mostly crafted in the 1980s and 1990s, and they take a very narrow, prescriptive approach that does not support innovation in technology and operations, including changes that improve safety, efficiency and mission capacity. The goal of SPD-2 and the NPRM is only to streamline the regulatory process and create a performance-based approach to regulating an innovative, evolving industry while encouraging it to become even safer.*
- *Remote Sensing Reform: Commercial Remote Sensing was born in the U.S. just as we were coming out of the Cold War, and the law and regulations the industry lives under were written with that mindset. Even so, the government all-too-often fails to live up to even those rules. In some cases, the government has taken years to respond, or has even never responded, to applications to use an innovative sensor, to improve available resolution, or sell data to a particular nation. Here, both the underlying statute and regulations need to be massively revised so that the government's actions are appropriate and transparent. CSF's members strongly support the approach taken by this Committee in 2017 with HR 2809, the American Space Commerce Free Enterprise Act.*
- *Non-traditional Commerce: Finally, it's time for the federal government to create a minimalist process for approving new commercial space activities by U.S. companies that go beyond launch and reentry, telecommunications, and remote sensing. Again, HR*

2809 provides a narrowly tailored approach to government oversight of those activities, which is why CSF has repeatedly endorsed its passage.

- *Airspace optimization: In the past few years, the increasing frequency of space launch and reentry activities, along with the emergence of new entrants to aviation, has raised congestion and safety concerns among some traditional aviation stakeholders. It is important, though, to keep the number of launches and reentries in context with the level of aviation activity in the NAS. As already noted, there were 32 commercial launches and reentries that transited the NAS in 2018. In a given year, approximately 15.5 million flights transit the NAS. So while 32 is a significant increase over the 12 launches 5 years ago, it is barely a blip on the radar. While there has been great progress in traditional aviation and commercial space transportation, like new entrants, drones, and personal air vehicles – all good and desirable developments – that progress is highlighting the need to improve the hardware, software, and human systems that manage the NAS. In particular, the way that we restrict airspace around launch or reentry events – an approach called "segregation" – is an inefficient use of the airspace. The problem is with the space launch risk analysis and air traffic control tools that the FAA uses to close airspace. Those tools are decades old, and not designed for today's aviation or space transportation needs. Stated simply, we close too much airspace, for too long, without real-time information available to air traffic controllers regarding the status of the launch or reentry. To improve the situation, we need to invest in fixing the following problems:*
    - *Obsolete tools that dictate the safety area around a launch or reentry - they are overly conservative and not dynamic;*
    - *The air traffic control systems' inability to accept data on the position and velocity of space vehicles; and*
    - *The lack of a tool for space operators to share and compare their launch and reentry schedules to aviation schedules to minimize conflicting operations.*

We are actively working with the aviation industry to address these challenges.

4. What cost savings, if any, have been realized—and/or are projected to be realized—due to reusable rocket technology for the commercial space market?

Significant for both orbital and suborbital launch vehicles. For example:

- *Suborbital: Blue Origin and Virgin Galactic reusable suborbital vehicles are flying suborbital payloads through NASA's Flight Opportunities program for $250,000. NASA's traditional expendable sounding rockets are flying suborbital payloads through NASA's ROSES program for at least $4 million. Simple math: reusable suborbital platforms are 1/16th the costs of expendable suborbital platforms. BIG cost savings.*

- *Orbital: SpaceX's reusable Falcon 9 and Falcon Heavy have already dramatically reduced the cost of orbital space access to both the Government and to the private sector. For example, U.S. expendable launch vehicles had no share of the global commercial launch market as recently as 2012 due to high costs. With the reusable Falcon fleet, the U.S. now controls nearly 70 percent of the world's addressable commercial market.*
- *By further comparison, launch services on Falcon Heavy have been sold for less than $130 million (see: AFSPC-52 contract award notice) with a capability of up to 15 tons to translunar injection (TLI). By comparison, the expendable SLS rocket will cost in excess of $1.5 billion per flight and will have up to 25 tons to TLI. Thus, for the same $1.5 billion cost, NASA could send 11 Falcon Heavy missions to TLI, delivering in excess of 165 tons, or more than 660% of the capability for the same cost. These are clear cost savings.*
- *Blue Origin is also developing its reusable New Glenn which will further provide further cost savings compared to expendable vehicles.*

a. How would any potential cost savings for the commercial market due to reusable rocket technology be assessed, and by whom?

Greater use by the market and simple arithmetic. Free-market competition does the work of deciding which product features, like reusable rocket technology, are the most innovative and cost-effective. Such competition also does the work of deciding which produce creatures add insufficient value to justify their expense. Thus, government procurement officials should take advantage of that work.[13]

b. **Could there be any drawbacks or unintended consequences to an increased utilization of reusable rocket capabilities across the industry?**

There are no drawbacks. Reusable launch vehicles are critical to reducing costs, improving reliability, and expanding the Government's capability to utilize space.

Just as there are no drawbacks or unintended consequences to other forms of reusable transportation like bicycles, cars, trains, and airplanes, there are only benefits to reusability.

Reusable rockets will allow NASA and the Air Force to spend more money on critical spacecraft capabilities and far less on launch. This is a clear "win" for the taxpayer and for the Government.

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[13] BRIEF OF AMICUS CURIAE TECHNET IN SUPPORT OF PLAINTIFF-APPELLEE. Available at: https://www.wsgr.com/attorneys/BIOS/PDFs/palantir.pdf

5. Could you expand on the comment in your prepared testimony that "commercial space is not about cost-plus contracting?"

To be precise: commercial space is underpinned by pay-for-performance, fixed-price contracts, agile and innovative development processes, flexibility and some level of risk tolerance, private capital co-investment, and more intensive innovation. By contrast, commercial space is not cost-plus contracting, staid solutions, or routine requirements creep. Cost-plus contracting incentivizes cost growth and schedule delays, since contractors inherently recognize they are awarded more by underperforming (see: any cost-plus program). The U.S. commercial space industry is driven by results and improving the Nation's access to space.

To be clear, fixed-price contracts result in space systems that are as safe, if not safer, than those developed under cost-plus contracts. There are the same safety and reliability requirements. But, programs are developed faster and at a far lower cost. Fixed-price contracts are the best of all worlds.

Please see answer to question 1 for additional description of what a commercial space contract looks like.

6. What are the opportunities, challenges, and associated policy issues that Congress should consider around large commercial satellite constellations?

- *Large commercial satellite constellations will offer significant new access to broadband capabilities not available to much of the United States and to the world today. Within the United States, this new expansion will bring high speed internet access to 30 million – 40 million unserved or underserved Americans today, dramatically improving the competitiveness of the American workforce.*
- *The challenge is for policy makers to enable those capabilities rather to impede those capabilities with premature and unproven regulations.*

7. In response to a question from Representative Wexton, you commented that the partnership between both government and commercial entities is the best way to ensure transparency in the safety process for commercial launches. Does the commercial space industry have standards or recommended best practices for accident investigations when both public and private partners are involved? If not, should they?

The commercial space industry works very closely with NASA and Government partners to develop the safest and most reliable spacecraft in history. For example, the SpaceX Crew Dragon has been designed specifically to meet NASA's most stringent safety requirements for flying astronauts, and NASA's engineers have worked closely with SpaceX to ensure compliance.

There is a well-established and long-standing anomaly investigation process between the private sector and the U.S. government when there is loss of life, government property, or third party property. This process involves a number of government agencies, including NASA, the Air

Force, the FAA, NTSB, and others. I would be happy to provide further detail to you in a briefing should you require that.

8. **As you discussed in your prepared testimony, the National Space Policy states that the U.S. government should not "discourage or compete with U.S. commercial space activities." How would you assess whether the government is competing with or discouraging commercial space activities that are still in planning phases, have not yet been fully demonstrated, and/or are reliant on the government as the sole customer?**

The Government is still competing with and discouraging commercial space activities that are still in planning phases, not yet been fully demonstrated, and/or are reliant on the government as the sole customer.

For example, the Space Launch System should not be offered as a "commercial" rocket to compete with the private sector for launches to Earth orbit, to the Moon, or beyond. This vehicle was entirely funded using Government dollars and leverages the use of Government facilities today at zero cost. When there are commercial vehicles that exist, the Government must not compete, as is the stated National Space Policy and National Space Transportation Policy.

The easiest way to find out if a government-led activity would/might compete with a commercial alternative is to ask industry. A request for information can obtain data to help determine if the good or service the government needs might be under development, or available in response to a commercial solicitation, so that the government can avoid the high financial and schedule cost of a more traditional government-led cost-plus development acquisition.

9. **Does the U.S. have in place the elements of a sustained, skilled workforce that can help ensure the growth and leadership of our U.S. commercial space industry?**
    a. **If not, what needs to be done to ensure the necessary workforce and skills are available to support the U.S. commercial space industry?**
    b. **To what extent would the lack of skilled employees impede the growth of the U.S. commercial space industry?**

No, much more needs to be done. For example, we need to improve the training of FAA AST personnel to understand the new technologies, systems, and operations concepts being pioneered in commercial space transportation today.

10. **Are there any projections for the number of future small-satellite launches that are anticipated to be carried out from government and commercial spaceports in the short- and long-term future? If so, what are they?**

We do not have any such projections, but the investment in ride-share and dedicated launch vehicles for small-satellites is a strong sign of growing interest in demand for those capabilities.

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Responses by Mr. Michael French

Responses to Questions for the Record of Mike French
Vice President, Space Systems
Aerospace Industries Association (AIA)

before the

Subcommittee on Space and Aeronautics
Committee on Science, Space, and Technology
U.S. House of Representatives

July 25, 2019 Hearing on "The Commercial Space Landscape: Innovation, Market, and Policy"

1. **During the hearing, we heard many different definitions of "commercial space" in different contexts. In the context of NASA, how would you distinguish a given program or activity as being "commercial" in nature, or not?**

   The National Space Policy provides a useful definition for distinguishing commercial programs and activities. Per the National Space Policy:

   > "The term 'commercial,' for the purposes of this policy, refers to space goods, services, or activities provided by private sector enterprises that bear a reasonable portion of the investment risk and responsibility for the activity, operate in accordance with typical market-based incentives for controlling cost and optimizing return on investment, and have the legal capacity to offer these goods or services to existing or potential nongovernmental customers."

   Relying on this definition can help all stakeholders involved in these important discussions reduce confusion or misunderstanding.

2. **Historically, the cost of launching to space has often been cited as one of the biggest barriers to entry into the space economy. Is that still the case?**
   a. **What are the biggest limitations or barriers right now for either new or existing companies to enter the space economy?**

   The biggest barrier to entering the space economy has been, and remains, high capitalization needs relative to the likely return of investment within typical investment timeframes. Lower cost smallsat-based systems and lower launch costs reduce the capitalization side of this equation. For some markets within the space economy, this has presented enough of a shift to attract private investment. This is especially true in the areas of communications, internet of things tracking/monitoring, and remote sensing. Not only do these business plans take advantage of lower cost smallsat technologies, but they also address existing markets with known customers and near-term potential revenue.

3. **What are the opportunities, challenges, and associated policy issues that Congress should consider around large commercial satellite constellations?**

The proposed increase in satellites, driven by telecommunication "megaconstellations," is staggering. Today, there are about 2,000 active satellites in orbit. And there are over 10,000 satellites planned to deploy in the next decade. Several policy issues that Congress will need to consider as a result include:

- Orbital debris mitigation – How do we limit future debris and how is that regulated?
- Space situational awareness – How do we know where other objects in space are and their trajectory? And, what entity (public and/or private) is responsible for tracking space objects?
- Space traffic management – How do we alert operators of potential collisions? What entity (public and/or private) is responsible for doing so? What are the incentives and/or compliance frameworks?
- Spectrum – With additional space users and increased terrestrial needs, how do we ensure adequate and interference-free spectrum?

These are not just future concerns. Just last week, a European Space Agency satellite had to maneuver to avoid a possible impact with one of SpaceX's initial sixty Starlink communications satellites. SpaceX plans several thousand additional Starlink satellites over the coming years.

Of note, the over 10,000 satellites currently planned may not come to fruition. Some of these systems still need to raise billions of dollars to fund their plans. For those that succeed in establishing an operational system, there are also remaining questions on whether the future market will support one or more of these systems given other space-based and future terrestrial competition.

4. **Your prepared testimony stated that "the extension of the public investment/private service model to new areas requires a nuanced understanding of the commercial space market today and a realistic assessment of its direction to ensure overall risks and opportunities are being considered." What are the main aspects of the commercial space market that should be understood by the government when using the public investment/private service model?**
    a. **How should government balance the associated risks and opportunities of a public investment/private service model?**

When using the public investment/private service (PIPS) model, the government needs to understand the current and near-term prospects of the commercial market at issue and industry's capabilities to provide the service at issue. Following this assessment, government should balance the risks and opportunities of using the

PIPS model by considering the overall impact on the government's core rationale (requirements) for undertaking the effort.

A fundamental assumption when using the PIPS model is that there is an existing or potential market for a commercial service. Without a market, the government will not be "one of many" future customers, and market incentives will limit genuine government/industry partnerships. This will result in public investment accounting for all, or nearly all, of the costs of developing the private service while also limiting the public's insight and control. Therefore, it is of primary importance for the government to determine the viability of the market underlying any PIPS model. In the case of NASA's commercial cargo program, there was a viable global launch market of over $5 billion annually justifying the use of PIPS. The result was significant investment from NASA's industry partners in this program.

In the case of an emerging market, it is important for the government to assess the timing of the market's emergence. Companies will typically make the level of investment required under PIPS considering a five to seven-year return on investment. Markets that will not materialize within this timeframe will be high-risk investment decision for most revenue-seeking firms to make, especially market driven small or medium sized firms where the required investment will be larger relative to their size.

The government's market assessment should also include an assessment of industry's capabilities to provide the service at issue. The PIPS model assumes the government's investment is needed to catalyze the development of the service needed. Accordingly, if the government believes this will become a future private service, the government should understand why it is not already an available private service. For example, are the capitalization costs too steep compared to the risk of return? Are there unknown technical hurdles? Is private capital not investing because there is no clear market, even if high risk?

Having completed this assessment, government should balance the risks and opportunities of using the PIPS model by considering the overall impact on the government's core rationale (requirements) for undertaking the program. For example, if the government's primary consideration is accomplishing a set mission in a certain time frame, but there is no viable market in that area, PIPS will likely be too risky to meet the primary consideration of timely mission success. One risk is that private companies will not put in significant amounts of private funding and the government could become the only customer of the service it pays to develop. This could create an overall more expensive service in the long term, while also limiting the government's overall ownership and insight of the service or capability it funded to developed.

A further risk is that only high-risk bidders will be able to compete, risking default. NASA recently saw an example of this. Less than two months after being selected for a nearly $100 million contract, one of the three companies NASA selected to take

payloads to the Moon dropped out of the contract due to "internal corporate challenges."[i] NASA had mitigated for this risk by selecting three providers. This was a recognition of the risk and thoughtful mitigation by the agency. The U.S. Air Force had another recent example, when small launch provider Vector paused its operations shortly after receiving a multi-million-dollar Air Force contract.[ii] Conversely, if the government's primary goal is market creation and economic development, it may be more willing to accept mission or schedule risk by employing a PIPS model in an area with an uncertain market.

Congress can play an important role in determining the core requirements and how these risks and opportunities are balanced. For example, setting the research, geopolitical, and international partnership aspects of a program as the core requirements, as was done historically with the International Space Station (ISS) program, could result in a different balance of the risks and opportunities than if Congress set the core requirements as economic development.

Of note, if the government does not use the PIPS model, it does not mean government is limited to another specific contract model. As discussed further below, the level of certainty around the government's requirements and development needs can be met by cost plus, fixed price, or mixed contracting models. All of these models can be utilized without including the public investment toward a private service feature.

5. **What are advantages and disadvantages of cost-plus contracting over other approaches and what role does cost plus play in meeting governments needs? What criteria, if any, exists to guide the government in deciding whether to use cost-plus or fixed-price approaches in contracting?**

The federal government as a whole, and NASA in particular, relies heavily on industry to accomplish its mission. In fact, over 80% of NASA's annual budget is spend on procurements.[iii] These procurements are accomplished through a range of contract types, including cost plus, fixed price, and time and materials – all with a mix of incentive options. At NASA, for example, contract types in a given year include firm fixed price, fixed price and cost plus with inventive fee, fixed price and cost plus with award fee, and cost plus fixed fee.[iv]

The Federal Acquisition Regulations (FAR) provide guidance on selecting contract types, with the underlying question being where the ultimate risk will tilt. The risk is shifted toward the government in a cost plus contract and toward the contractor in a fixed price environment. This determination is driven by how well the risks, requirements, and price of the service or item being procured are understood.

According to the FAR, "A firm-fixed-price contract, which best utilizes the basic profit motive of business enterprise, shall be used when the risk involved is minimal or can be predicted with an acceptable degree of certainty." 48 CFR 16.103(b). Fixed price

contracts are generally not used in cases of complex requirements and less understood risks. As the FAR explains:

> "Complex requirements, particularly those unique to the Government, usually result in greater risk assumption by the Government. This is especially true for complex research and development contracts, when performance uncertainties or the likelihood of changes makes it difficult to estimate performance costs in advance. As a requirement recurs or as quantity production begins, the cost risk should shift to the contractor, and a fixed-price contract should be considered." 48 CFR 16.104(d)

NASA's procurements have followed this framework. According to the NASA Inspector General, "[t]raditionally, NASA has used cost-plus contracts to design, develop, and build new and unproven space capabilities such as the Space Shuttle, elements of the Constellation Program, the Space Launch System heavy-lift rocket, and the Orion Multi-Purpose Crew Vehicle."

Department of Defense guidance provides additional context:

> "The cost reimbursement family of contracts is used when circumstances do not allow for requirements definition sufficient for the execution of a fixed-price contract, such as in:
>
> - Research and development;
> - Major system development;
> - Prototype development and testing;
> - or Low rate initial production."[v]

The urgency of the government's needs is also a consideration. As describe by the FAR, "if urgency is a primary factor, the Government may choose to assume a greater proportion of risk or it may offer incentives tailored to performance outcomes to ensure timely contract performance." FAR 16.104(f)

Contract vehicle type is often mistakenly used as proxy for effectiveness or performance. Rather, a Department of Defense assessment showed, "no statistical correlation between performance and broad contract type."[vi] According to the DOD assessment:

> "'Cost-plus versus fixed-price' is a red herring. The distinction between cost-plus and fixed price contracts is not the divide on effectiveness. Rather, the emphasis should be on matching incentives to the situation at hand instead of expecting fixed-price contracting to be a magic bullet. Fixed-price contracts have lower costs because they are used in lower-risk situations, not because they control costs better. Moreover, prices on fixed-price contracts are only 'fixed' if the contractual work content and deliverables remain fixed, which is often not the case. Our analysis showed that objectively determined incentives were the

factors that controlled costs, not selecting cost-plus or fixed-price contract types."[vii]

6. **The National Space Policy states that the U.S. government should not "discourage or compete with U.S. commercial space activities." How would you assess whether or not the government is competing with or discouraging commercial space activities that are still in the planning phases, have not been fully demonstrated, and/or are reliant on the government as the sole customer?**

The National Space Policy provides guidance on the U.S. government's space activities given different existing levels of commercial activity. In determining whether the government is discouraging or competing with commercial space activity under the National Space Policy, it should first be determined if the activity in question is "commercial" as defined by the National Space Policy itself.

Several aspects of the policy are relevant. First, the policy defines "commercial" overall as goods, services, or activities, "provided by private sector enterprises." Second, the policy states the government should, "[p]urchase and use commercial space capabilities and services to the maximum practical extent when such capabilities and services are *available in the marketplace* and meet United States Government requirements." [emphasis added]. Therefore, these areas of the direction in the National Space Policy were not intended to apply to not-yet-existing activities. While policymakers could take a different path to encourage an emerging area of activity, this should be viewed as an additional policy choice, versus relying on an application of this language. Relying on this language would muddle what is a generally well understood and followed policy as it applies to currently available commercial products.

The National Space Policy does provide direction that government systems should only be developed when in the national interest and "no suitable, cost-effective" commercial service "is or will be" available. In this case, the government is advised to be highly cautious in assessing a capability that "will be" available. The government should assess the status of the capability and whether it is at a point in development that the government can precisely determine if it is "suitable and cost effective." The risk of taking a different approach would be that a system in the national interest is delayed or not deployed.

The National Space Policy also provides direction on how to address those activities that are "provided" and "available," but where the government is the sole customer. Specifically, National Space Policy language defines commercial services as having to: (1) "operate in accordance with typical market-based incentives for controlling cost and optimizing return on investment," and (2) "operate in accordance with typical market-based incentives for controlling cost and optimizing return on investment."

Depending on the service at issue, this may require an assessment of the government's role in supporting the activity and whether the service could be provided absent that support. Given this analysis, the underlying activity may not in fact be "commercial" and not the type of service contemplated for protection from competition under the policy. Again, policymakers could take a different path to encourage this type of activity, but this should be viewed as an additional policy choice, versus relying on an application of the National Space Policy that was intended to protect commercial activity.

A related aspect of the National Space Policy is its direction to "[e]nsure that United States Government space technology and infrastructure are made available for commercial use." NASA's recent ISS commercial pricing models are a good example of NASA's leveraging a national asset to enable commercial use without disrupting the international, human spaceflight, and science missions on ISS. Opportunities may also exist to leverage other aspects of NASA's infrastructure, whether the Space Launch System or future aspects of NASA's lunar architecture.

7. **Assessments and projections of trends in the commercial space market and the various sectors is important to understand. Are there any independent market assessments and forecasts for the commercial space industry released/updated regularly?**
   a. **What role, if any, should the federal government have in gathering, reporting and/or assessing commercial space markets and making them available to the public?**

Several commercial firms provide regular assessments of the space economy. For example, AIA member companies Avascent, Booz Allen Hamilton, Boston Consulting Group, and Deloitte are some of the firms that conduct space economy assessments and forecasts. Government policy-making and the public interest would benefit from the regular gathering, reporting, assessing, and sharing of data of this type and should be encouraged by the Congress.

8. **Does the U.S. have in place the elements of a sustained, skilled workforce that can help ensure the growth and leadership of our U.S. commercial space industry?**
   a. **If not, what needs to be done to ensure the necessary workforce and skills are available to support he U.S. commercial space industry?**
   b. **To what extent would the lack of skilled employees impede the growth of the U.S. commercial space industry?**

The future success of the aerospace industry depends on building a diverse 21st century workforce that taps into the best talent in communities across the country. Our current workforce has grown to more than 2.5 million people, representing 20 percent of the U.S. manufacturing workforce. But we will need to further expand and diversify our workforce if we want to continue leading the world in technology and innovation. Nationwide, technology professionals are in high demand, creating competition for a skilled workforce across all industry sectors. As a result, the

aerospace industry has continuing workforce needs across the board, including to help conduct space missions and operations; manage cyber network operations and cybersecurity; carry out cloud computing, data science, and analytics work; and perform advanced manufacturing.

While the United States has the right elements of a skilled workforce in place (i.e., a well-educated workforce, a robust higher education system, and increasing federal, state, and local government investments in training and reskilling), more must be done to ensure that these pieces are continued and built on to sustain and advance U.S. leadership in commercial space and aerospace in general. AIA has been encouraged by the bipartisan and bicameral congressional efforts in 2019 that look to address the vital need for college and skills-training affordability and workforce diversity and inclusivity. For example:

- Skills Investment Act (HR 898/S 275) – Expands tax-favored Coverdell education savings accounts to allow use for skills development expenses.
- Jumpstart Our Businesses by Supporting Students Act (HR 3497/S 839) – Makes Pell Grants available to students enrolled in short-term community college job training programs.
- Equality Act (HR 5/S 788) – Provides employment non-discrimination protections based on sexual orientation and gender identity.
- Cybersecurity Skills Integration Act (HR 1592) – Establishes a pilot program to award grants for cybersecurity education within higher education programs.
- Workforce-related provision of the House and Senate National Defense Authorization Act of 2020 and a NASA Authorization Act.

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i https://spacenews.com/commercial-lunar-lander-company-terminates-nasa-contract/
ii https://www.losangeles.af.mil/News/Article-Display/Article/1955385/space-and-missile-systems-center-awards-49-million-small-rocket-program-orbital/
iii NASA Annual Procurement Report, Fiscal Year 2018, https://www.nasa.gov/sites/default/files/atoms/files/annual_procurement_report_2018_final.pdf
iv NASA Annual Procurement Report, Fiscal Year 2018, https://www.nasa.gov/sites/default/files/atoms/files/annual_procurement_report_2018_final.pdf
v DOD Guidance on Using Incentive and Other Contract Types, https://www.acq.osd.mil/dpap/policy/policyvault/USA001270-16-DPAP.pdf, 2016
vi DOD Guidance on Using Incentive and Other Contract Types, https://www.acq.osd.mil/dpap/policy/policyvault/USA001270-16-DPAP.pdf, 2016
vii Performance of the Defense Acquisition System, 2014 Annual Report, https://www.acq.osd.mil/fo/docs/Performance-of-Defense-Acquisition-System-2014.pdf

Appendix II

Additional Material for the Record

LETTER SUBMITTED BY REPRESENTATIVE KENDRA HORN

July 25, 2019

Representative Kendra Horn
Chairwoman
Subcommittee on Space and Aviation
Committee on Science, Space, and Technology
U.S. House of Representatives
2321 Rayburn HOB
Washington, DC 20515

Dr. Brian Babin
Ranking Member
Subcommittee on Space and Aviation
Committee on Science, Space, and Technology
U.S. House of Representatives
2321 Rayburn HOB
Washington, DC 20515

Dear Chairwoman Horn and Ranking Member Babin,

I write to you on behalf of the Coalition for Deep Space Exploration, a coalition of more than 70 companies and organizations in the commercial space industry, with regard to today's hearing of July 25, 2019 entitled "The Commercial Space Landscape: Innovation, Market and Policy". I appreciate the opportunity to comment, and commend you, and members of the subcommittee for conducting today's hearing on this important topic.

The particular focus of my letter is launch regulatory reform. On 15 April 2019, the Federal Aviation Administration (FAA) published a Notice of Proposed Rulemaking (NPRM) meant to streamline commercial launch licensing. This action was taken as a result of Space Policy Directive 2 (SPD-2), issued by the President and prioritized by the Vice President and National Space Council. We support this effort and applaud all who have directed and participated in this challenging task.

The commercial space industry is constantly evolving and innovating in ways that strengthen America's status as the premiere leader in space. This requires a regulatory agency that is willing to work with industry to achieve fit-for-purpose regulations that enable a thriving commercial space industry. Critical to our nation's success is that public safety remain the *top priority* of the FAA's Office of Commercial Space Transportation (AST), both for public support and assured operations. This holds especially true when launching from sites such as Kennedy Space Center, Cape Canaveral Air Force Station, Vandenberg Air Force Base, and Wallops Flight Facility. Damage to or destruction of flight hardware, neighboring operations, range assets, and shared infrastructure and commodities could cripple the nation's access to space and leave life-saving national assets grounded for months or even years.

To date, the general consensus of the Coalition members who have chosen to engage on this issue has been support for AST's efforts and the content of the NPRM. Further, we do not support an indefinite rulemaking process, but would like AST to bring it to conclusion as soon as possible. It is our belief that any further improvements can be made to the current NPRM. Implementation – sooner rather than later - will reduce regulatory uncertainty and allow operators to begin working with AST to take advantage of the flexibility to result from the NPRM. It will also provide ample opportunity to tailor the license application process and propose alternate compliance methods, all while maintaining the highest levels of public safety.

For further information, I encourage you to review the individual and joint comments submitted by Coalition companies to Docket No.: FAA-2019-0229. We look forward to the release of the draft advisory circulars and stand ready to continue our work with the FAA on the important issue of regulatory reform.

Thank you again for the invitation to comment on this important topic.

Sincerely,

Mary Lynne Dittmar, Ph.D.
President & CEO
Coalition for Deep Space Exploration
mary.lynne.dittmar@spacecoalition.com

CDSE
1545 18th St NW
Unit 514
Washington, D.C. 20036
(202) 747-4378