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Chairman Cruz, Ranking Member Sinema, and distinguished members of the Committee—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 also appreciate the opportunity to honor the 50th anniversary of Apollo 11 by looking at NASA’s exploration plans and examining how our past experiences and lessons learned can guide space exploration efforts going forward. In addition to NASA’s world-leading space exploration capabilities, the United States now has a vibrant, highly capable commercial space sector that can accelerate and complement NASA’s internal development efforts. As we look to the future, true public-private partnerships between this domestic industry and the Government represent the most effective path to rapidly, safely, and cost-effectively return to the Moon and venture on to Mars.

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 U.S. 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.

NASA has embarked on an ambitious effort to commercialize low-Earth orbit (LEO), to establish a long-term presence on the surface of the Moon, and to send astronauts to Mars. These bold commitments should be commended. Over the last two decades, NASA has fostered a nascent domestic spaceflight industry into becoming a highly diverse and capable portfolio of companies. NASA has 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 foresight and meticulous cultivation of this industry, American companies support critical space exploration and national security needs today, in addition to the commercial marketplace.

Policymakers have recognized the benefits of these kinds of partnerships since the earliest days of the space program. The National Aeronautics and Space Act of 1958 outlines one of NASA’s core missions is areas as: “[t]o seek and encourage, to the maximum extent possible, the fullest commercial use of space.” National Space Policies from both Democratic and Republican administrations have stressed the importance of the commercial space sector. And Space Policy Directives 1, 2, and 3, each issued over the past two years, take further steps to strengthen the partnership between Government and industry and to remove barriers to industry growth. And, under your leadership, this Committee has taken important steps to facilitate commercial space industry development, most recently with its efforts on the Space Frontier Act.

Today, I will outline CSF’s perspectives as to how we all can collectively advance our Nation’s space goals through innovative, strategic partnerships with American industry.

I. America's Vibrant, Highly Capable Commercial Space Sector

The United States established its leadership and dominance in space with government-funded and government-controlled space exploration.¹ 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 in large part to NASA's leadership, pathfinding, and partnerships with the private sector in the decades since, a broad and dynamic space industry has emerged. Since 2000, investors have supported 375 private space companies with nearly \$19 billion of private capital.² As NASA continues to drive the frontier outward with groundbreaking research in space, the commercial sector is making space affordable and accessible to everyone.

Today, the United States is enjoying a renaissance in space, with commercial space enterprises playing a leading role. To update the Committee on the commercial space industry's recent major milestones:

- 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 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 several 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. And, Virgin Orbit has completed several captive carry tests of its LauncherOne vehicle attached to a 747 aircraft in preparation of flights to space in the near future.
- 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 in an all-American system, ending the country's drought on 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 test 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.

¹ Space, The Final Economic Frontier, Journal of Economic Perspectives, Matthew Weinzierl, Spring 2018. Available at: <https://pubs.aeaweb.org/doi/pdf/10.1257/jep.32.2.173>

² Proprietary Data, Space Angels, September 30, 2018.

- 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 has supported more than 750 payloads at the ISS to-date and has deployed 243 satellites through a commercial dispenser, in partnership with NASA. The company is also building the first-ever commercial airlock, designed to be integrated with the ISS in the coming years.
- 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 and Bigelow 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 interesting 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 SSL (a subsidiary of Maxar Technologies)—to conduct advance development on human lunar lander concepts.

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

II. Apollo 50th: Partnerships with Commercial Industry are Fundamental to Achieve a Sustainable Return to the Moon

50 years after Americans first stepped on the surface of the Moon, President Trump, NASA and Congress have established a national commitment to return Americans to the Moon—not just to plant footprints and flags, but to establish long-term habitation and sustainable activity on the lunar surface. This will provide the spaceflight community a valuable proving ground for NASA’s goal of sending astronauts to Mars.

This ambitious objective should be applauded and, if executed appropriately, will serve to reinforce American leadership in space as international competitors like China, Russia, and India focus their own exploration efforts on the Moon. In January 2019, China achieved a major milestone in its lunar space exploration program, landing the Chinese space agency’s Chang’e-4 spacecraft on the far side of the Moon for the first time in history.³ This achievement builds on the China’s 2013 success of landing its first rover on the Moon, joining the United States and the Soviet Union as the only nations to have carried

³ The New York Times, “New Chapter in Space Exploration as China Reaches Far Side of the Moon,” January 2019. Available at: <https://www.nytimes.com/2019/01/02/world/asia/china-change-4-moon.html>

out a soft landing on the Moon. In September this year, India hopes to become the fourth country to soft land on the Moon.⁴ The United States should ensure it remains the leader in space exploration—and private industry is here to help.

Long-term, sustainable exploration on the lunar surface, and ultimately Mars, requires an integrated effort that includes the development of capable landers, the operation of robust deep space habitats, and routine transportation of astronauts and large cargo. Public-private partnerships with commercial companies are fundamental to developing these capabilities. NASA’s fiscal year 2020 budget request and budget amendment prudently highlight partnerships with commercial providers as a key tenet of this strategy.

Undeniably, the systems that brought Americans to the Moon during the Apollo program were and remain a marvel. But, as we consider our options for the future, we should look not only to technologies of the past, but to the new advancements of today. CSF companies are proud to be playing a role in this new era.

III. Flexible COTS-like Development Agreements and Firm, Fixed-priced Services Contracts

These capabilities are already helping to support NASA’s exploration goals, and they will continue to support NASA as it works to return to the Moon. As this Committee looks to how best ensure the country’s ongoing leadership in space, it must carefully review development and acquisition efforts to ensure responsible use of finite taxpayer dollars and to encourage, rather than hamper, rapid innovation.

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. 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 that NASA brings to the market as a customer, numerous private companies are developing lunar systems and signing commercial contracts with customers around the world.

NASA should consider the Commercial Cargo program and its development effort—Commercial Orbital Transportation Services (COTS)—as the ideal model as it looks to structure the lunar lander and habitat elements of its exploration architecture. 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

⁴ CNN, “India hopes to become fourth country on the moon in September,” June 2019. Available at: <https://www.cnn.com/2019/06/13/india/india-moon-mission-intl/index.html>

demonstrated the efficiency of such partnerships.”⁵ 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.”⁶ Simply put, this approach works.

As NASA looks to define a development and acquisition approach for its lunar lander and habitat systems, it should adopt a COTS-like structure that would:

- Leverage the commercial industry’s ability to innovate quickly, improving safety and reliability. The sector’s high cadence of development and test-like-you-fly approach provides for far greater system maturity than relying purely on simulations and ground tests. This approach was what NASA followed during the Apollo era, and it should return to its roots.
- 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.
- Use firm, fixed-priced, pay-for-performance, milestone-based agreements that drive toward a successful conclusion and focus 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 schedules.
- 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.
- 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.
- 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.
- Encourage new, non-traditional companies to work with NASA. Traditional FAR-based contract requirements are complex and costly, which often deters small, less-experienced companies from working with the Government. 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 companies to do business with the Government.
- Facilitate the development of new markets and leverage market-driven pricing to support Government requirements and missions.

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, 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) drawing funding 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 the agency. Both options are demonstrably 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

⁵ 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>

⁶ 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.

agency.⁷ Instead, the Committee should encourage NASA to follow a third way that avoids these pitfalls: 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.”⁸

To succeed, NASA must employ fast, flexible, lean contracting agreements like SAAs to incentivize rapid and affordable development of U.S. transportation and habitat systems to safely land humans on the Moon by 2024.

IV. Lessons from Apollo: Constant Innovation and an Eagerness to Test New Concepts

By any accounting, the Apollo program represents humankind’s greatest and most inspirational technological achievement. It was an enormous undertaking, costing about \$177 billion in 2019 dollars. Only the building of the Panama Canal rivaled the Apollo program's size as the largest non-military technological endeavor ever undertaken by the United States and only the Manhattan Project to build the atomic bomb in World War II being comparable in a wartime setting.⁹ As we honor the 50th anniversary of Apollo 11, CSF commends the Committee for examining how our experiences and lessons learned can guide space exploration efforts going forward.

Several important lessons from Apollo need to be remembered and should guide space exploration efforts going forward. Iterative, evolutionary, and risk-tolerant development was the cornerstone of NASA’s Apollo-era progress:

- From 1958 to 1963, the Mercury program conducted twenty uncrewed development test flights, and six successful flights with astronauts. Mercury’s early uncrewed test flights helped NASA find and fix problems. For example, of the twenty uncrewed test flights, half of the flights resulted in failure or partial success. But, the agency learned how to put astronauts in orbit around Earth. It learned how people could live and work in space, and it learned how to operate a spacecraft in orbit.
- Following Mercury, during a 20-month span of the Gemini program from March 1965 to November 1966, NASA flew ten Gemini crews to Earth orbit, each testing new capabilities in preparation for the landing on the Moon.
- And, of course, Apollo followed these programs. From 1961 to 1966, NASA launched increasingly capable iterations of the Saturn rocket 14 times to learn valuable insights into the complexities of building and launching a large cryogenic system so that, before the decade was out, they had the capability to land people on the Moon.

⁷ 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>

⁸ 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>.

⁹ <https://history.nasa.gov/Apollomon/Apollo.html>

The Apollo-era attitude that enabled NASA to land on the Moon 50 years ago was based on constant innovation and an eagerness to test new concepts. These are the same principles that underpin the success of the commercial spaceflight industry today. For example:

- Small-, Cube-, and Nano-Satellites are increasingly effective and efficient platforms for remote sensing and communication applications, and commercial providers developing and operating these systems are revolutionizing the satellite industry.
 - From 2013 to 2018, Planet, an Earth imaging company, launched nearly 300 satellites into orbit, 150 which remain active. Combined, they constitute the largest constellation ever put into orbit.
 - Planet is not alone, companies like Advanced Space, Amazon, Astranis, BlackSky, Maxar Technologies, and SpaceX are each developing their own systems, with SpaceX launching the first 60 satellites of its Starlink broadband constellation this past May.
 - Thanks to the advances by the commercial space industry, NASA is now utilizing these platforms to augment and support the scientific investigations carried out by the agency's larger flagship missions.
- Suborbital reusable launch vehicles are providing low-cost and frequent access to suborbital space for humans and research payloads that are contributing to NASA's science, exploration, and technology development missions. During a six-month span from December 2018 to May 2019, Blue Origin and Virgin Galactic flew to space and back four times, carrying 54 research and technology payloads, 24 of which were NASA-sponsored payloads testing new capabilities for the agency.
- The commercial industry has established and self-funded the world's first marketplace of diverse reusable rockets, both suborbital and orbital, which successfully launched for commercial and government customers.
- Commercial landers: successfully hotfired large lander engines, which have been under development for several years, and exclusively developed with private capital;
- Commercial heavy lift: successfully launching the world's most powerful operational rocket by a factor of two, exclusively developed with private capital; and successful test-firings of large methane rocket engines and development of heavy lift launch vehicles;

The need for flexibility serves as another important lesson for Apollo. For example, NASA was the first federal agency to be granted Other Transaction Authority (OTA) in the 1958 Space Act, in order to provide NASA with the full flexibility to beat the Soviets in the space race to the Moon.¹⁰ Now, as then, NASA must adapt when new technologies and architectural approaches are introduced.

V. Conclusion

With the technological advancements and increased knowledge achieved through decades of work by NASA in deep space, including Mars, the United States is now well-positioned to build upon and surpass our past achievements in space. With NASA resources and expertise, coupled with American ingenuity, the principles of free enterprise, and the benefits of competition, the United States can do more in space than has ever been accomplished previously. We just need to appropriately recognize and leverage our advantages.

¹⁰ "This was 1958 and NASA was a big deal," said Ralph Nash, a government procurement law expert and founder of the Government Contracts Program at George Washington University's National Law Center, where he is a former dean of graduate studies and professor emeritus. "We were in a space race with the Russians and President [John] Kennedy said we would get to the moon in this decade," he explained. "This was there to give them full flexibility." See here: <https://www.nextgov.com/it-modernization/2018/03/otas-scary-new-contracting-model-isnt-scary-or-new/146964/>

As the Nation commits to returning to the Moon by 2024, it is buoyed by a vibrant commercial space industry powered by agile and innovative development processes, flexibility and some level of risk tolerance, private capital co-investment, and more intensive innovation. In its return to the Moon, NASA does not need to go it alone, nor should it. The most efficient and realistic way of returning to the Moon is a hybrid approach between Government and commercial partners.

Going to the Moon is hard. Staying there is harder, and moving beyond to Mars is harder still. But American industry stands ready. The Commercial Spaceflight Federation supports NASA's fiscal year 2020 budget request and budget amendment to more fully utilize public-private partnership programs and commercial service buys to accelerate cost-effective deep space exploration objectives, including sending landers and astronauts to the lunar surface by 2024.

It is now time for the United States to build on Apollo's important legacy. To do so, CSF recommends the following:

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. Competitively awarded, firm, fixed-price contract with payment for meaningful deliverables and milestones, not just for effort;
4. Maintain competition throughout—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.

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.

Indeed, NASA's budget amendment states that to "achieve our goals, we will not go forward alone," and "strong commercial partnerships will accelerate our human exploration plans." We are ready to take that step with NASA, and we look forward to continuing to work with this Committee to the Nation sustainably returns to the Moon and ventures to Mars. Chairman Cruz, Ranking Member Sinema, I appreciate your invitation to testify before the Committee today. Thank you for your attention, and I look forward to your questions.