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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.