**Testimony before the Subcommittee on Space,**
**Committee on Science, Space, and Technology, U.S. House of Representatives**

**Hearing on America's Human Presence in Low-Earth Orbit**
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Chairman Babin, Ranking Member Bera, and distinguished Members of the Committee, thank you for the opportunity to testify today.

NASA's FY19 budget proposes to end direct financial support for the International Space Station (ISS) by 2025, and transition to a commercially-operated Low-Earth Orbit (LEO) capability, essentially turning NASA from a landlord to a tenant in LEO. This transition can occur in two primary ways. The ISS could be *privatized*, as in all or parts of it could be taken over by a private entity, and operated on behalf of the government, much like most DOE labs are today. Alternatively, a private sector entity could build, launch, and operate a *commercialized* LEO-based platform for profit.

In a recent study conducted at the Institute for Defense Analyses (IDA) Science and Technology Policy Institute, my colleagues including Keith Crane, Benjamin Corbin, Reina Buenconsejo and I addressed this second option: Could a privately owned and operated, permanently-crewed space station, that may look nothing like the ISS, generate sufficient revenues to cover its capital and operations costs, without government subsidies?[1]

## Assessment of the Market Case for a Private Space Station

For the purpose of the study, we assumed that a private space station would be wholly owned and operated by private parties who would decide the station's capabilities, the markets it would serve, and the prices it would charge for its services. The private parties' customers could be commercial or government entities—whoever would be willing to pay for the services provided by the station. Additionally, we assumed that the space station would need to be human-tended or human-inhabited, located in LEO, and able to engage in many revenue-generating activities.

We identified activities that could generate a revenue stream for the station. We modeled the station as an industrial park in space, where researchers, astronauts, businesses, and non-profit organizations rent parts of the station to conduct their activities. We then generated estimates of revenues that the space station could earn by leasing space or

[1] The report is available at https://idalink.org/P8247

providing services in support of these. Activities related to media, advertising, and education were developed with input and review from experts employed at the global communications and advertising agency firm Saatchi & Saatchi in New York. For each activity, we made assumptions that generated lower revenue projections based on less optimistic assumptions and higher revenue based on more optimistic assumptions. We summed the lower projections to generate an aggregate “low” estimate and summed the higher projections to generate an aggregate “high” estimate. If a private space station were to be built, actual revenues could be lower or higher than either of the projections presented in my testimony.

To generate these estimates, all in constant 2015 dollars, we held discussions with over 70 individuals engaged in activities in space or with detailed knowledge of such activities. In many cases, activities (and their costs) on the ISS were used as points of departure, with appropriate adjustments for private sector operations. Using information from these individuals and from other sources on market size, competing technologies, and costs of conducting the activity on a space station in LEO, we developed individual methodologies to estimate revenues from each activity for the space station.

We selected concepts of space stations that might best serve the activities identified and generate revenues. For each of the selected space station concepts, we generated parametric cost models, and used engineering design parametric relationships to estimate the costs of developing and constructing the station, the costs of operations once built, and costs of resupply and personnel. We then compared annualized costs to potential revenue streams to determine if prospective revenues might be sufficient to cover a station’s costs and potentially attract private investment.

The analysis incorporated many assumptions, the most critical of which was a major reduction in the price of launch in the timeframe from 2025 and beyond. We assumed launching an astronaut would be priced at about $20 million, a reduction of over 75 percent compared to the current price of launching U.S. astronauts on Russian spacecraft; encapsulated cargo, at $20,000 per kilogram (kg), a decrease of about 66 percent from the current price; full launch, at $62 million, a reduction of about 50 percent; and propellant transport, $5,000 per kg, a service for which there is currently no price because it is not yet available.

STPI identified 21 activities that have the potential to generate revenues on a private LEO space station. The activities fell into five categories:

- Human habitat or destination for private space flight participants or government astronauts

- Activities supporting the satellite sector, especially on-orbit assembly of satellites
- Manufacturing products and services for use in space and on Earth, especially high-grade silicon carbide and exotic fiber optic cable
- Research and development (R&D), testing, and Earth observation
- Media, advertising, and education

We ruled out products such as growing human organs in space that we believe are more than a decade away from becoming a reality. Markets like these or others we have not encountered in our research may emerge, generating revenues not included in this analysis. Some markets for space station-based products and services could experience much more rapid growth than we have assumed here. Conversely, there is the risk that products or services projected to generate large revenues fail to do so. R&D efforts may make it possible to develop products on Earth or on high-altitude controlled, suborbital, or parabolic platforms at lower cost rather than producing those products on orbit.

Other challenges make our projections uncertain. For example, we do not yet know the extent to which potential future Chinese or Russian space stations might draw away opportunities from a U.S. private space station.

The low estimate for total annualized revenues from activities conducted on a space station is $455 million and the high estimate is $1,187 million. Figure 1 below shows the low and high revenue estimates for each activity, and Figure 2 shows the combined estimates for low and high revenues. Figure 2 also highlights that two categories of activities account for most of the projected revenues. For the high estimate (right column, Figure 2), manufacturing products in space is the largest contributor to overall revenues, accounting for nearly 35 percent. Potentially profitable manufacturing operations for exotic optical fibers drive these revenues. Revenue from satellite support—specifically assembly in orbit—was a close second, at 30 percent of total revenues. In the case of the low estimate (left column), the manufacture of exotic optical fibers alone accounted for over half of total revenues.

U.S. Government activities—principally government astronauts, R&D, and assembly of government satellites—comprises 14–39 percent of the revenues in low and high scenarios. NASA in particular pays the station operator at least $40 and $80 million for services rendered in the low and high estimates, respectively; these payments do not include other expenses such as transportation to the station for sovereign astronauts or research experiment development costs. NASA does not pay more for services than other customers do for the same services, nor does NASA act as an anchor tenant.

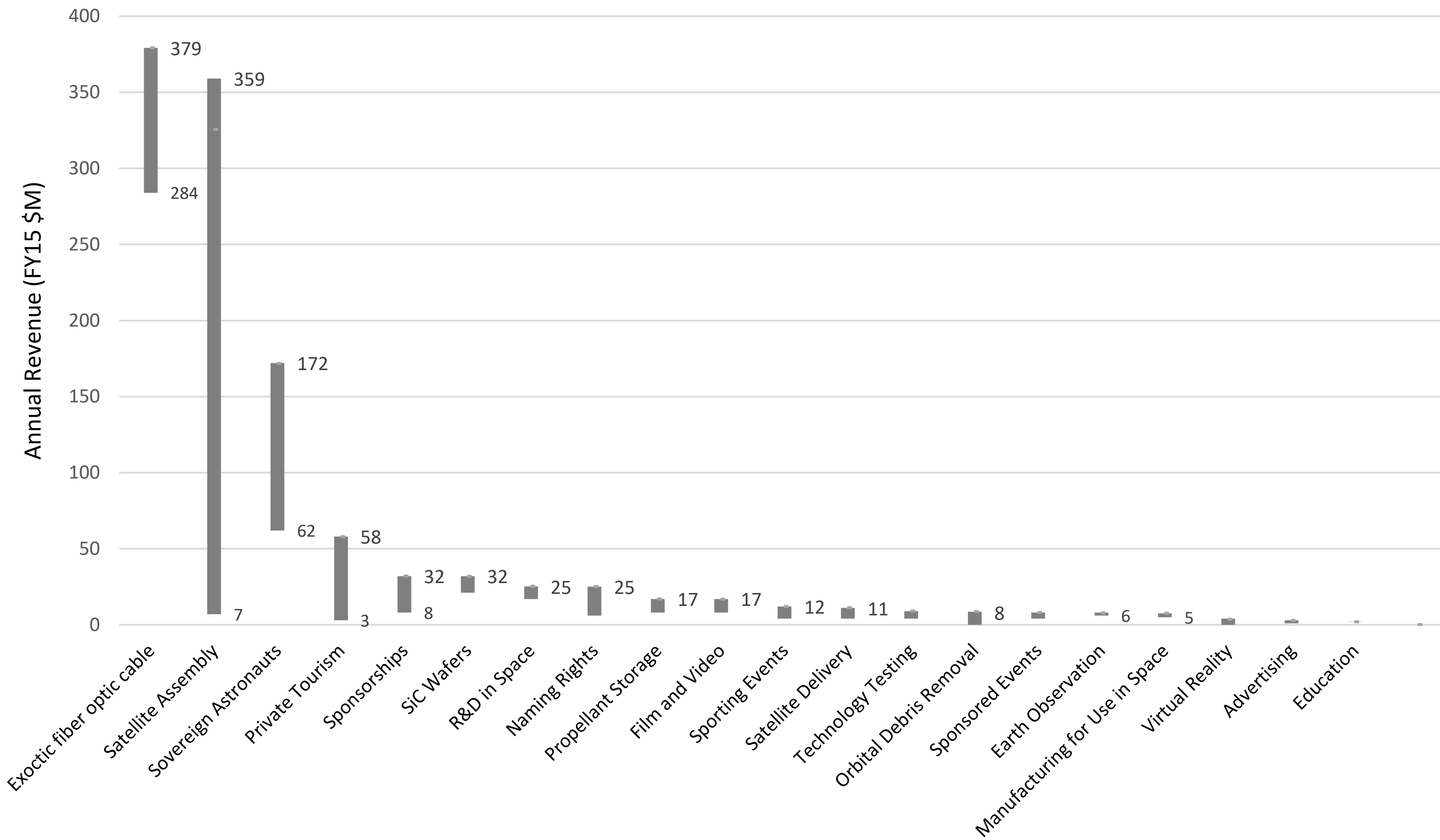


**Figure 1. Projected Revenues for a Private Space Station (FY15 Millions of Dollars)**

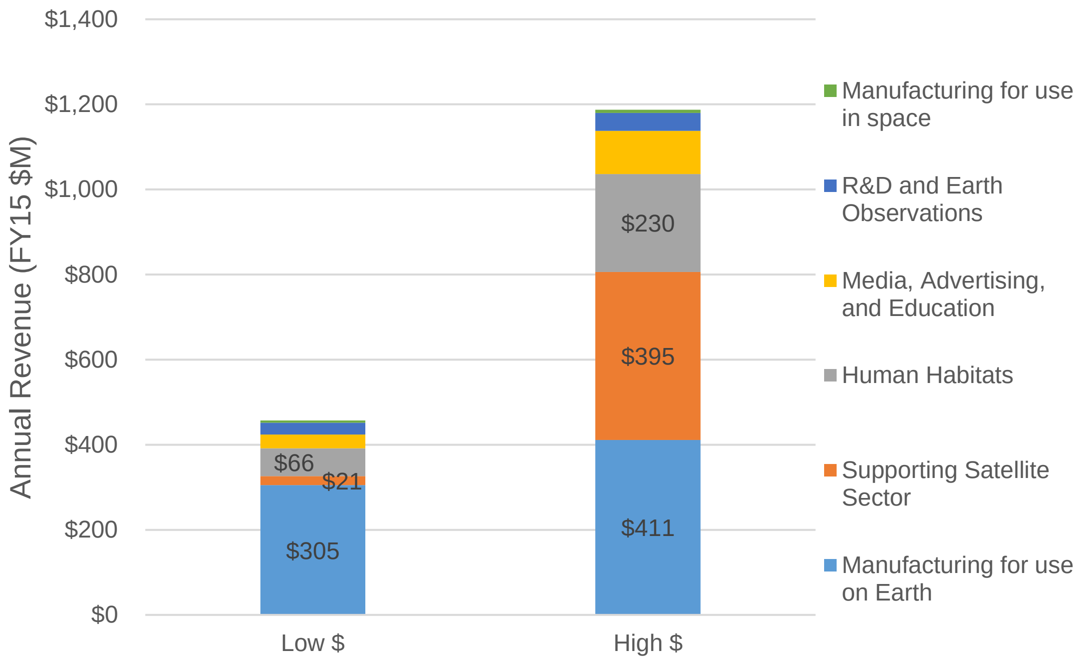


**Figure 2. Distribution of Projected Annual Revenues for the Space Station**

Note: Numbers may not add up due to rounding

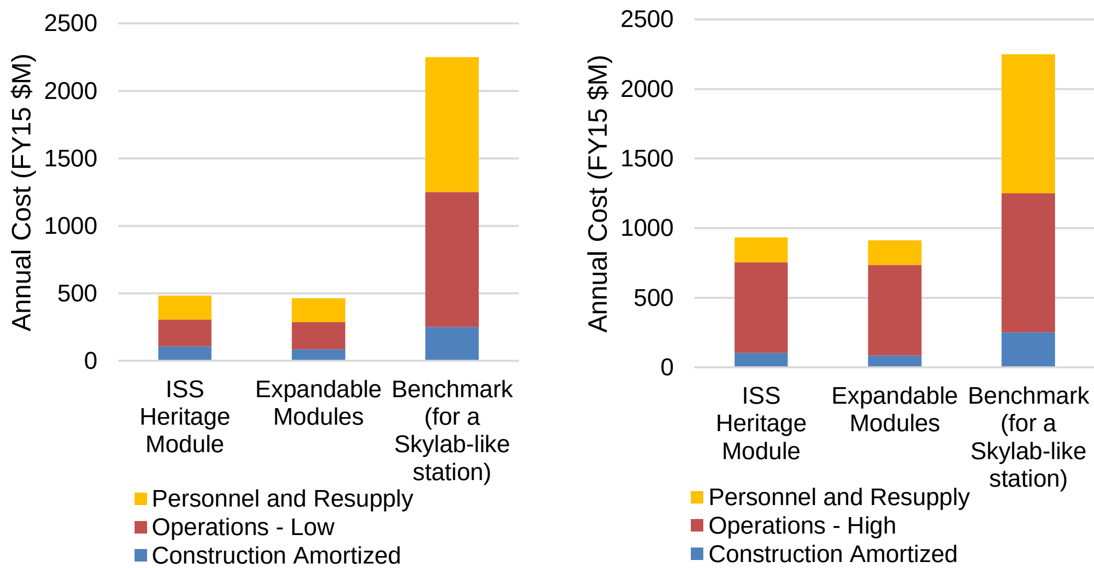


**Figure 3. Comparison of Low (left) and High (right) Estimated Annualized Costs of Three Private Station Concepts**

These revenue estimates are highly uncertain, and based on extrapolations from current conditions, as they are for revenues 10 years from 2016. The estimates should not be considered lower or upper bounds; rather, they represent our best attempts to provide data-driven estimates of potential revenues based on different sets of assumptions. The difference between our low estimate and high estimate is large—$732 million. This substantial difference reflects the highly tentative nature of these estimates.

While the projections are per force speculative, they do provide empirically-based assessments of almost all of the activities that have been discussed as potential revenue sources for a privately-owned and operated space station. These estimates are designed to help policymakers assess the prospects that the private sector might invest in such endeavors.

We evaluated several prospective concepts for a space station that could house all the activities for which we generated estimates of potential revenues, and estimated the costs of two of them: a space station constructed from ISS-heritage modules, and a space station constructed from expandable modules. In addition, we used a publicly available estimate of the costs of a Skylab-like station as a benchmark.

The comparison of low and high estimated annualized costs of the three private station concepts shows a breakdown of estimates of costs for all three concepts for three elements: (1) the costs of designing and constructing the modules, (2) annual costs of operations, and (3) costs to the station owner of transporting their astronaut employees to and from the station and resupplying the station (Figure 3). For ease of analysis and based on precedent, construction costs are amortized over 10 years. For operations costs, as a result of the lack of consensus among our interviewees, we generated a low and a high estimate. As the figure below indicates, the annualized low estimate cost of a private space station was $463 million, and the high, our benchmark, was $2.25 billion.

Figure 4 maps the low and high estimates of annual revenues and annualized costs for the station. As can be seen, even in a best-case scenario where launch costs are significantly lower than they are today, and other optimistic assumptions, neither estimate of annual revenues covers the estimate of annualized costs for the high estimate (our benchmark). Out of the four cases, only in the high-revenue, low-cost scenario do revenues exceed costs.

We conducted a simple financial analysis to determine whether a station might generate a sufficiently high rate of return to attract private investors. For the instances in which station costs were low (the higher cost scenario ended up losing money), we calculated the internal rates of return for a prospective privately owned and operated space station. In the case of high revenues and low construction and low operations costs ($200 million), the internal rate of return is 40 percent, exceeding even the highest venture capital fund hurdle rate. When we use high revenue and low construction costs but high operations costs ($650 million), the internal rate of return falls to 18 percent. The station loses money in the other scenarios. *Venture capitalists whom we interviewed noted that the projections of revenues and costs are so uncertain that they would* *have no interest in financing a space station until projected revenues from these activities show signs of materializing.*

We also conducted sensitivity analyses on launch costs, a major driver of both revenues and costs. As Figure 5 shows, if launch costs were to fall further, either as a result of a technology breakthrough or a government subsidy, the estimates of revenues for the low-cost scenario would increase by 23 to 53 percent, for the high- and low-revenue scenarios, respectively. If the government subsidizes launch costs entirely—as it does today for many activities on the ISS—revenues for a private space station would go up by 46 to 106 percent, for the high- and low-revenue scenarios, respectively. These subsidized revenue estimates do not take into account a potential increase in demand due to a lower cost to access the station.

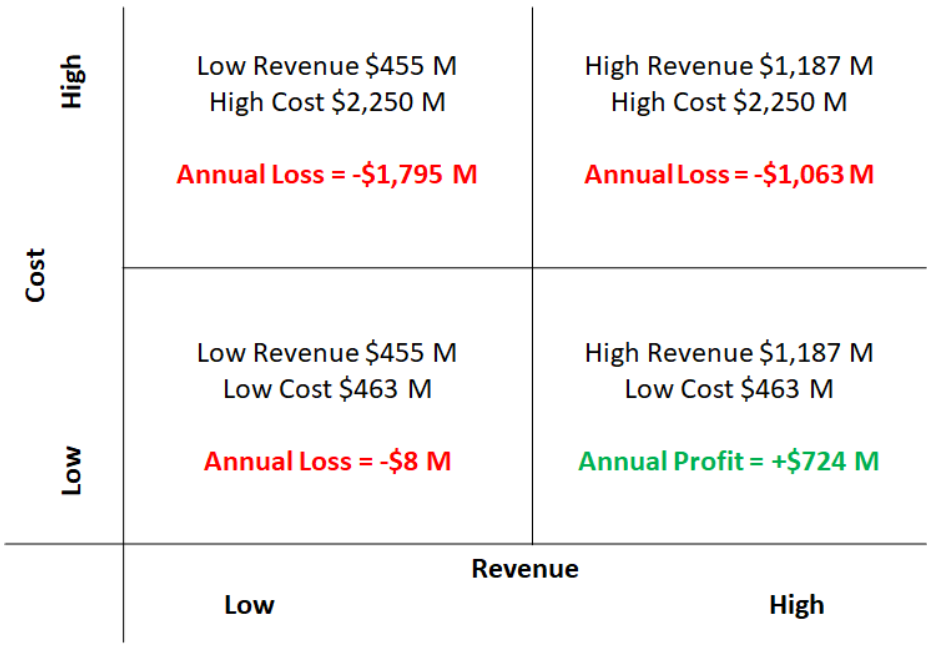


**Figure 4. Estimated Annualized Cost and Revenue Estimates for a Private Space Station**

In our interviews with the venture capital community, we learned that revenue streams were seen as too far out in time and too uncertain to warrant venture capital or angel investment, although a wealthy philanthropist might choose to self-finance the project. *In our estimation, it is unlikely that a commercially owned and operated space station will be economically viable by 2025*.

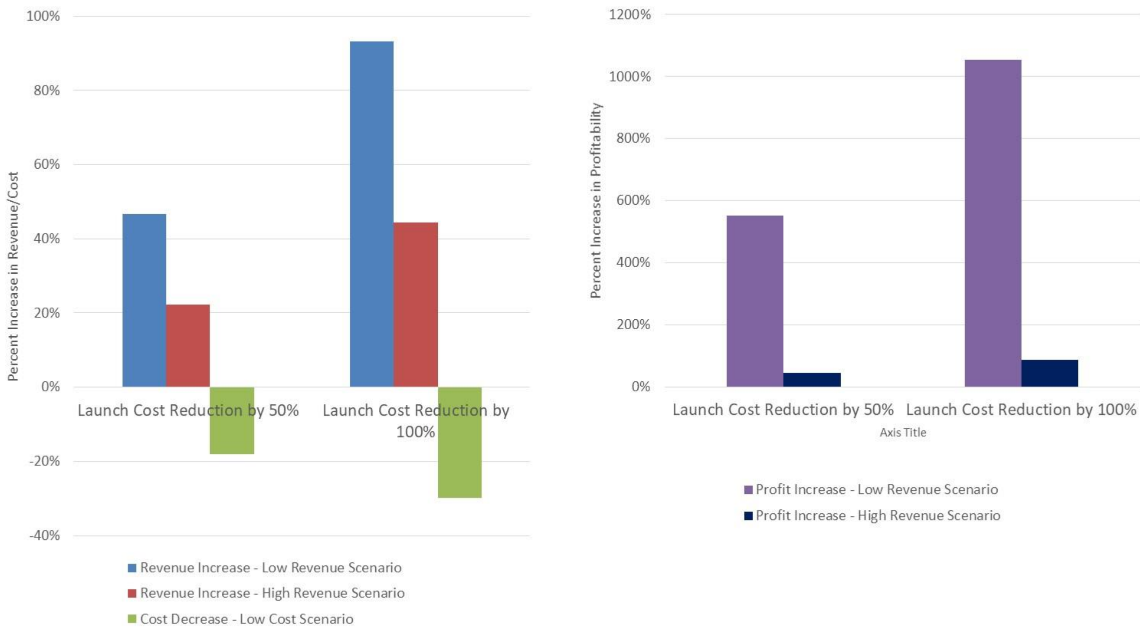


**Figure 5. Effect of Reduced Launch Cost on Revenues, Cost, and Profitability**

## Conclusion

There are some caveats that go with the findings. Some markets for space station-based products and services could experience more rapid growth than we assumed, and revenues could be greater than estimated. There is also a risk that products or services that are projected to generate large revenues might fail to do so. For example, new manufacturing techniques to produce goods terrestrially that can currently *only* be produced in microgravity would drastically change the analysis, making it more difficult for a private space station to generate profit. The growing availability of suborbital and parabolic flight opportunities, as well as temporary, uncrewed orbital capsules, could both take potential business away from a permanent station *and* provide an on-ramp to develop new markets. Last but not least, possible future Chinese or Russian space stations, subsidized by their respective governments, could also draw business opportunities away from a private space station.

If a permanently-crewed commercial space station in LEO is a critical element of United States' leadership in space, without a ready commercial case in place by 2025, there are several options that merit further exploration:

- The ISS could be extended through 2028. Continuing to operate, maintain and resupply the station will cost about \$3–4 billion a year, which would take resources away from deep space exploration, and affect the timeline for the return of U.S. astronauts to the

Moon. It may also take away opportunities from a rapidly burgeoning private sector that feels ready to lead activities in LEO.

- The ISS or modules within it could be privatized. Depending on how the deal is structured, this could in principle yield cost savings, although that cannot be assumed. As interviewees in our study indicated, the station was not designed to be operated inexpensively, and maintenance costs are likely to increase as elements are operated past their designed lifetimes. Privatization would entail additional challenges. For example, we have commitments to international partners, and their views would need to be considered.

- NASA could select a private entity to operate a commercial platform at an inclination and orbit that maximizes their potential profit. While this option is best suited to help LEO commercialization, it will likely require some level of a government subsidy for the commercial operator. *In our analysis, an annualized payment of about $2 billion could cover the cost of a private station even in the case of zero revenues.*

A deeper dive into the trade-offs among these options may be crucial before any permanent decisions on America's human presence in LEO can be made. And regardless of the pathway chosen, the ISS needs to be doing everything it can today to help private companies reduce risk in profit-making activities in space.

I'd like to conclude my remarks by observing that there are likely many technological, legal, regulatory and international challenges at this time of transition. I am confident however that the United States will overcome these challenges through its ingenuity, daring, and ambition, attributes I consider core to the American space enterprise.

Thank you!