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Chairman Babin, Ranking Member Edwards and members of the Committee, on behalf of The Boeing Company, thank you for the opportunity to testify today to provide an update on Boeing's role in NASA's next steps in deep space exploration and our deep space habitat work as we build the stepping stones toward a human journey to Mars.

Boeing is proud to be NASA's prime contractor on the International Space Station and a partner on the Commercial Crew Program, where we are building the CST-100 Starliner to transport our crews from U.S. soil to and from low-Earth orbit.

We are also under contract with NASA to build the core stages and avionics of the Space Launch System, the largest and most powerful rocket ever built. The SLS enables exploration beyond low Earth orbit and will take us to cislunar space, Mars and beyond.

In addition, Boeing is under contract as part of NASA's NextSTEP program. NextSTEP is a public-private partnership model that seeks commercial development of deep space exploration capabilities. We are working with NASA to enable more extensive human space flight missions in the Proving Ground around, and beyond, cislunar space--the space near Earth that extends beyond our moon.

<u>NASA's Journey to Mars</u>

Let's start with the fact that sending humans to Mars will be challenging! Imagine an 800 to 1,100 day mission with up to 45 minutes of delayed communication. When you're behind the sun, there are two weeks of blacked out communication between you and any help from mission control back on Earth. Once in the vicinity of Mars, after seven to eight months of travel, there is a thin atmosphere to enter as you face dusty conditions, attempting to stick the landing of a 20 to 30 ton payload. And you'll need to bring your oxygen with you—about 20 tons, which is required for your ascent back to the rendezvous vehicle. Sounds like an

excerpt out of Andy Weir's "The Martian," but I assure you, the challenge is very real.

Overcoming these obstacles is doable, but it will take a deliberate, phased approach to send humans to Mars and then return them safely to Earth. If you ask NASA-and the world… they will agree that the returning safely to Earth part is pretty important.

ISS: Deep Space Platform

I'd be remiss if we talk about our journey to Mars without first speaking about the International Space Station, the base camp, and our platform for proving space technology and science that will be vital to a human mission to Mars.

Through the remainder of the station's life, our focus is on reducing cost, increasing efficiencies and maximizing research utilization while supporting a new commercial model for transportation. Over the past 10 years, we have reduced the cost of our sustainment role by more than 30 percent.

ISS continues to be used for developing multiple technologies for deep space exploration such as critical life support systems and environment monitoring systems. NASA is developing and testing highly reliable life support systems to address needs for future exploration habitation systems. This includes important carbon dioxide removal systems, oxygen generation systems, and the systems needed to monitor and detect things like trace gases, water contaminants and microbes. All of this is critically important to learn on the ISS before we make longer duration missions farther into our solar system, such as future missions to Mars.

Lessons learned from ISS

We've already learned a lot from the ISS for how we live and work in space. We've seen groundbreaking research on ISS that will help humanity on the ground and we're also seeing invaluable research that will help us sustain life on the three-year round trip journey to Mars.

In March, Astronaut Scott Kelly returned after a 340-day historic mission aboard the ISS. During that time the station crew conducted almost 400 investigations, many which included research into how the human body adjusts to

weightlessness, isolation, radiation and the stress of a long-duration space mission.

From ISS operations we've learned that we'll need an environmental control and life support system that is more efficient at recycling air and water in deep space applications. We've learned that we'll face the challenges of the effects of radiation on the body and on hardware. Typically, large amounts of metal is the answer for protecting against an event like a solar flare, but mass and long duration deep space missions don't mix, and we'll need to develop a more efficient way to protect our Astronauts on the way to Mars.

We've learned that closing the business case for commercial involvement in low-Earth orbit has been challenging. Through the Center for the Advancement of Science in Space (CASIS) we've found that investors will spend hundreds of thousands of dollars, but we don't have the "killer app" that will stimulate the $1-2 billion it takes to fully sustain the station.

We've also learned that international involvement in the station has been a key to success. The ISS has also served as common ground for the U.S. to work closely with other nations including Canada, Japan, Russian and eleven member states from the European Space Agency. We hope to leverage those existing relationships in international partnerships as we build the bridge to deep space. The ISS also serves as a bridge for other international diplomatic discussions. As a leader and the major supporter of the ISS, the United States is in position to continue to champion a global vision for space exploration.

Commercial Low-Earth Orbit Habitats

Current U.S. policy is also examining the feasibility of deploying commercial habitats to eventually replace the capabilities currently provided by the International Space Station. While the technical difficulty of this application is well understood, estimating the commercial market growth and operating a commercial habitat profitably represent the greatest challenges. Today the ISS through CASIS is starting to reveal commercial demand for micro-gravity science applications. The current commercial utilization environment is best characterized as heavily subsidized with the government covering the large obligations including, transportation, utilities, and astronaut time. Current ISS operations requires two-thirds of the ISS budget to transport crew and cargo. At

this time it is too early to make valid projections of a commercial market, yet alone predict the impacts created by the transitioning from a heavily subsidized to a commercial business model.

Why Cislunar?

On ISS we are continuously learning from maintaining complex operations and that work is informing our efforts for how we live and work in deep space. Boeing is leveraging NASA's investment, lessons learned and our experience of building, integrating and operating the ISS into how we build a habitat for deep space.

We cannot afford to leave a gap between our human presence in space, or risk losing support from interested international partners. NASA and the industry must ensure a smooth transition from a continuous human presence in low-Earth orbit to deep space.

After ISS, the next step in our journey to Mars is the cislunar proving ground. In the area around the moon we plan to establish a habitat that is essential for proving out second generation technologies in deep space like a closed-loop environmental system, solar electric propulsion technology and radiation-hardened avionics.

The cislunar proving ground ensures responsible risk management prior to a Mars mission and allows us to reduce the amount of staging for a mission outside of Earth's gravity well. The moon is close enough to return our astronauts to Earth in three to seven days in case of an emergency.

Enabling International and Commercial Partnerships

Not only does a cislunar habitat enable NASA's missions, but it opens the door to additional government and commercial partnerships. International partners and private enterprises have expressed interest in a variety of moon missions from human missions to the surface, scientific robotic missions to explore the dark side of the Moon and studies to validate the validity of future resource utilization to potentially develop oxygen, water and fuel, which may be on ramped once proven.

NASA and its international agency partners will pave the way for this future commercial utilization of the moon, however it's crucial as we focus on Mars that commercial partnership does not become part of the critical path.

At the conclusion of the proving ground missions we envision a shakeout mission that would simulate an Earth-independent Mars mission. This mission would ensure the highest probability of success and simulate the transit time from the Moon to Mars while checking out life-sustaining equipment.

Pieces to Mars

Including the cislunar habitat there are six essential pieces to get to Mars. The first two pieces, the Space Launch System and Orion are already being built, and showing great progress. Those pieces get us in and out of the Earth's gravity well.

Two more pieces are required to go between Earth and Mars; a deep space tug and a deep space transportation habitat derived from the cislunar habitat. Transportation from the Moon to Mars will be in the form of a solar electric tug that will harness the power from the sun to drive the propulsion system. The crew will live in the deep space habitat during the seven-to-eight-month transit time to Mars. We'll leave that habitat in the Martian orbit as the crew descends to the surface. That brings us to the final two pieces. The lander, which will have an inflatable heat shield, will take the crew through the Martian atmosphere and then land the crew on the surface of Mars. After the crews have completed their mission on the surface, we'll need the final piece, a small rocket to propel the crew back up through the atmosphere, back to the habitat.

All of these six pieces are feasible within projected NASA funding.

Conclusion

Somewhere in the world is a student, about ten to twenty years old, probably studying math or science--that student will be the first person to ever set foot on Mars. That's amazing to think about.

Interest in NASA's future is at a high, and the next generation is excited about deep space exploration and a human mission to Mars. Applications for the 2016 Astronaut Corps reached an all-time record of 18,300 entries. I can imagine many of those entrants dream about one day stepping foot on the Martian surface.

Today's Astronauts will prove the technologies in low-Earth Orbit and in cislunar space that the next generation will take with them to Mars.

We at The Boeing Company are a committed partner to NASA's human journey to Mars. We have a difficult journey ahead, but we're poised and excited to stand with and support NASA as they plant the first American flag on Mars.

Thank you.