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Chairman Babin, Ranking Member Bera, and Members of the House Committee on Science, Space, and Technology, Subcommittee on Space:

Thank you for allowing me to speak today. I am testifying in my personal capacity. Though much of today's hearing is on the Mars 2020 and Europa flagship missions, a discussion of NASA's planetary science program would be incomplete without also talking about the balance between them and smaller planetary projects.

The Psyche Mission

I am the Principal Investigator of the NASA Psyche mission, which was selected as the 14th in the Discovery program within NASA's Science Mission Directorate. The Psyche mission is scheduled to launch in August 2022, rendezvous with the asteroid Psyche in January 2026, and orbit it for 22 months.

Psyche is a metal world with diameter about the width of Massachusetts, and surface area greater than the state of Texas. We have explored rocky worlds like Mars and the Moon, and icy worlds like Ceres, and worlds with gas surfaces like Jupiter and Saturn, but we have never explored a metal world. Here I will make a brief description of the Psyche mission and its purpose.

Beneath our feet is 1,800 miles of rock, and then the Earth's core, which is primarily iron and nickel metal. Venus, Mars, Mercury, and the Moon have similar differentiated structures, with rock overlying a metal core. The Earth's core is the source of our magnetic field, which protects us from radiation and helps to shield our atmosphere from erosion by the solar wind. The metal core of a terrestrial planet, therefore, is central to a planet's habitability, and yet we have never seen or sampled our core. We can only study it remotely through seismic waves and heat flow measurements. The pressure at the core is three million times surface atmospheric pressure, and its temperature is 10,000F; we are never going to our core.

The leading hypothesis for the formation of Psyche is that it is the core of a small early-formed planet that was stripped of its rocky exterior by multiple hit-and-run impacts in the early solar system. The period of intense impacts that either broke new small planets apart or accreted them together to form the planets we have today was just the first five million years after the first solids formed in our solar system, the equivalent of the first minute and a half if our solar system's 4.56 billion years were scaled to 24 hours.

Computer models of planetary formation indicate that it was possible, but rare, for a single small body to experience multiple stripping impacts with no additive impacts. Indeed Psyche is the only large, round metal world in our solar system: it is both unique and improbable.

The science objectives of the mission are to determine whether Psyche is a core, or if it is material with a previously undiscovered origin; to determine the relative ages of regions of its surface; to compare its composition to models for the Earth's core; and, for the first time, to characterize the morphology of a metal world. What do craters into metal look like? Could Psyche bear glittering cliffs of metal and green pyroxene crystals?

The Psyche mission is led by Arizona State University and managed by NASA's Marshall Space Flight Center. NASA's Jet Propulsion Laboratory is responsible for mission management, operations, and navigation. The spacecraft's solar-electric propulsion chassis will be built by Space Systems Loral, a new partner for NASA that brings special economies as an experienced commercial vendor. The spacecraft's payload comprises an imager from ASU and Malin Space Science Systems, a magnetometer from UCLA and MIT, and a gamma-ray and neutron spectrometer from the Applied Physics Laboratory. The Psyche mission is also scheduled to carry an important technology demonstration, the Deep Space Optical Communications instrument, to test laser communications between deep space and the Earth.

By making this voyage to a metal world, our nation is creating another first in space exploration history. This concept has captured the imaginations of people around the world: in the few months since selection we have been featured in over 100 articles and news stories, with outlets including the *Washington Post*, *The New York Times*, and the *Wall Street Journal*.

Exploration is a human imperative. It is stamped into our DNA. And we have a space future, as a society, as a species. Psyche raises the level of excitement with a new kind of world and a voyage of pure exploration. We are seeing and measuring things that have neither been seen nor measured by humankind before.

We will learn not just about the processes and materials that create habitable planets, we will also take the first steps toward our space resource future: we believe that Psyche consists almost entirely of iron, nickel, copper, and a variety of trace metals. This confluence of motivations, from understanding the science of planetary origins, to the structure and composition of the Earth's deep interior today, to the first investigations into a critical future space resource, make Psyche an especially interesting target.

NASA Mission Portfolio Balance

The Psyche mission is P.I.-led. The science is highly focused and the spacecraft can be produced from high-heritage components, allowing a relatively quick timeline, keeping the tempo of exploration up.

Tempo is critical – we need to exercise, maintain, and build our precious space engineering and science workforce. Fallow times translate directly into job loss, loss of institutional memory, and loss of the ability to do the great space exploration feats we are so rightly proud of. Thus, Discovery and New Frontiers missions and their planned regularity of selection are critical not just to producing new discoveries, but to maintaining our ability to move into our space future.

All missions engage students in science and engineering, and on Psyche, we also engage student interns in education, outreach, and art. Maximizing the opportunities for younger students to get involved with missions is a goal we are grappling with. We would like to enable more students from universities without active space science and engineering faculty to participate; this is a challenge for NASA and for all educational institutions.

To balance the relatively smaller P.I.-led missions, NASA manages large flagship missions. Some great challenges in understanding our universe are too large for the tempo and size of a P.I.-led mission. Missions facing significant technology development challenges or complex measurements demanding a large payload require more direct leadership from NASA.

Technology development is critical for progress, but it is expensive and time-consuming, and must be specifically encouraged and planned for. Without explicit funding for technology development, the low-risk strategy of using high-heritage technologies will prevail; we need both solid high-heritage technology and innovation for the future. Further, flagship missions are a perfect platform for combining the goals of robotic and human space exploration, as, for example, the MOXIE experiment on the Mars 2020 rover.

Flagship missions also engage a broader swath of the community, through competed calls for instruments, for example, which P.I.-led missions generally do not employ. This more equal opportunity has a greater possibly of bringing new groups onto missions, but the project scientist then has the challenge of organizing and uniting disconnected subteams.

A challenge to all missions is the transition required for the lead researcher to move from a traditional academic or research position to organize, inspire, and lead large interdisciplinary teams. These skills are not generally taught to scientists or engineers. We are working at ASU to change this, and to produce a new generation of scientists and engineers with the skills to lead and thus to solve bigger problems, to wield the multiple capabilities of an interdisciplinary team, and to move us faster into a positive future.

Thus, I strongly support the Planetary Decadal Survey's conclusions about the advantages, indeed the necessity, of having a balanced portfolio including small and medium P.I.-led missions on a regular tempo as well as flagship missions.

The Imperative of our Space Future

At its heart, space exploration is far more than the privilege and right of a developed country. It is the future of exploration for humankind, and also an opportunity – an opportunity to build a better educated, better trained, more united society. An opportunity to create the positive future we envision. The size and influence of these projects provides the leverage we need to inspire education, to stimulate innovation, to motivate society. Every time we do the most extreme of human technological accomplishments by sending a spacecraft off our Earth to make new discoveries, we inspire the people around the world to take a bolder step in their own lives and in their own communities.

At ASU I am also co-chair with President Michael Crow of our new Interplanetary Initiative. In this initiative, we are bringing together the societal, educational, and technical capabilities and concepts required for our space future. The university is creating an exploration model as a methodological approach to learning. We need to produce a critical mass of people who are attracted to the unknown, learn how to ask good questions, are willing to pursue answers with fractional steps of progress, and know how to be leaders and build teams.

All this ideation is initiated by the processes and vision of NASA. Space exploration inspires and motivates us to act not just in space, but also on Earth. NASA's programs exist on multiple scales, for good reason, to invigorate science, education, technology development, and the STEM workforce.


PSYCHE
JOURNEY TO A METAL WORLD
Prepared for the National Aeronautics and Space Administration Science Mission Directorate: Submitted in response to AO NNH14ZDA014O
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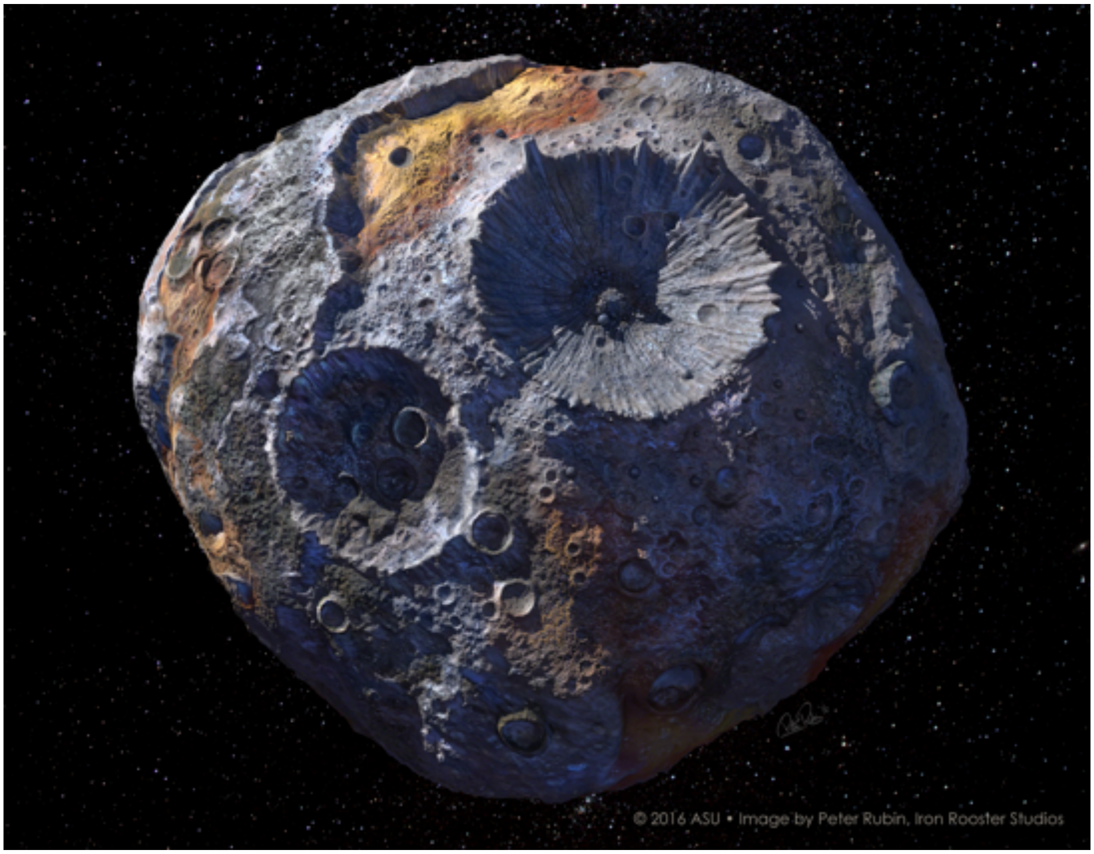

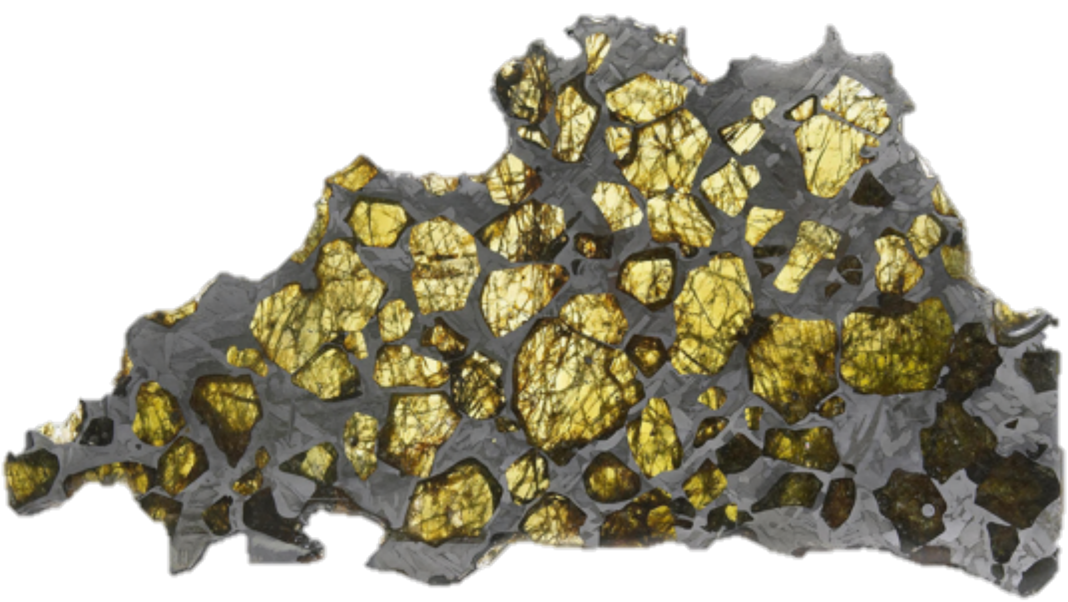

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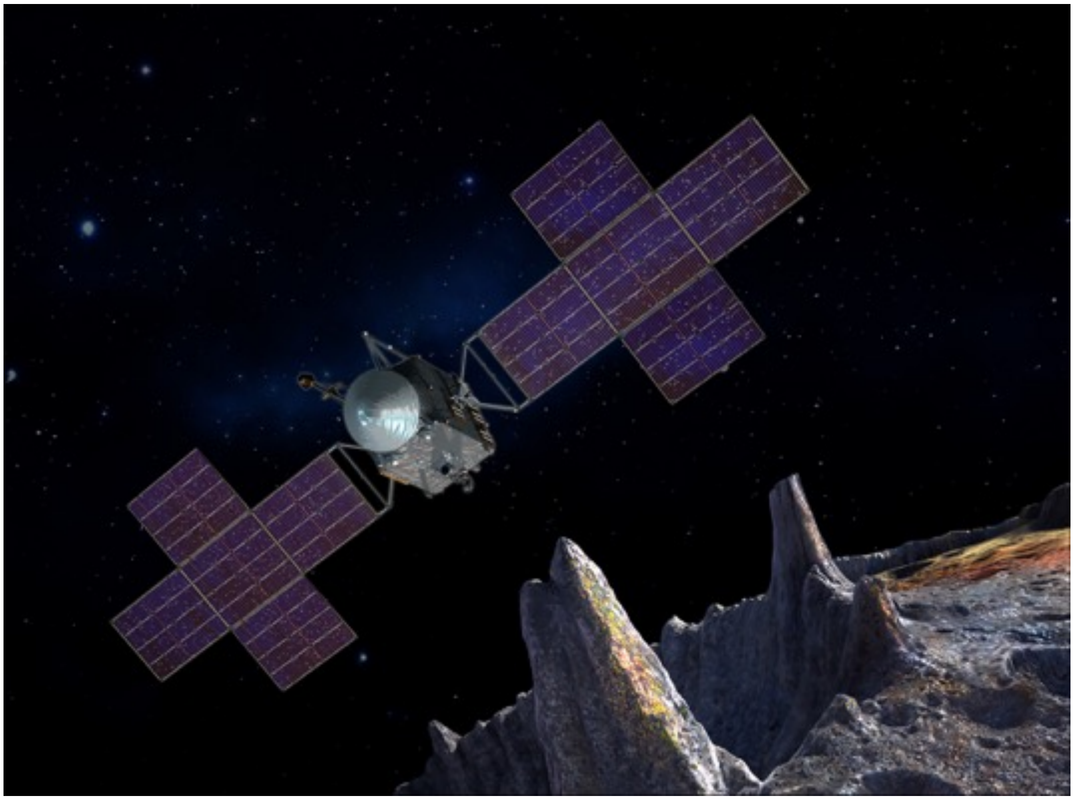
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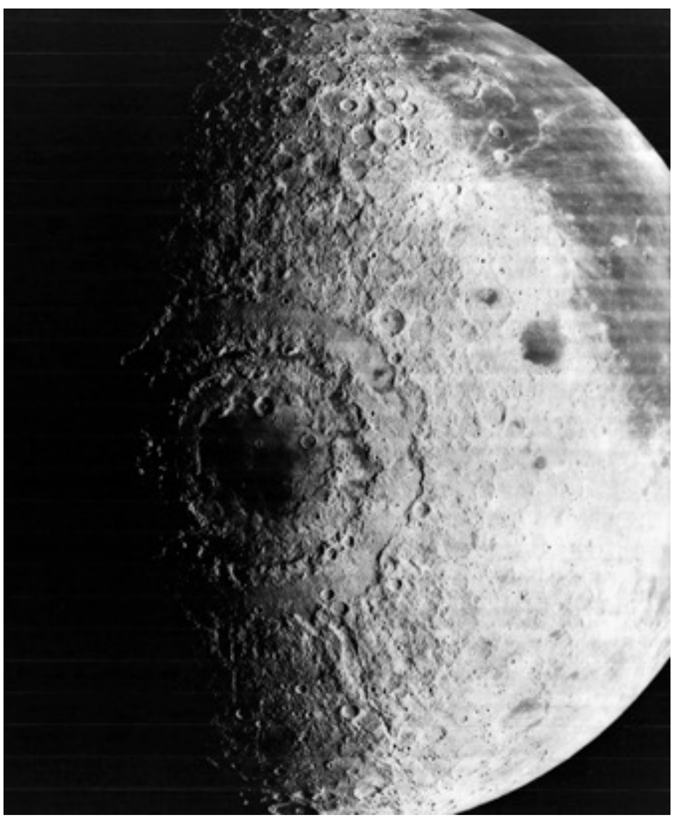
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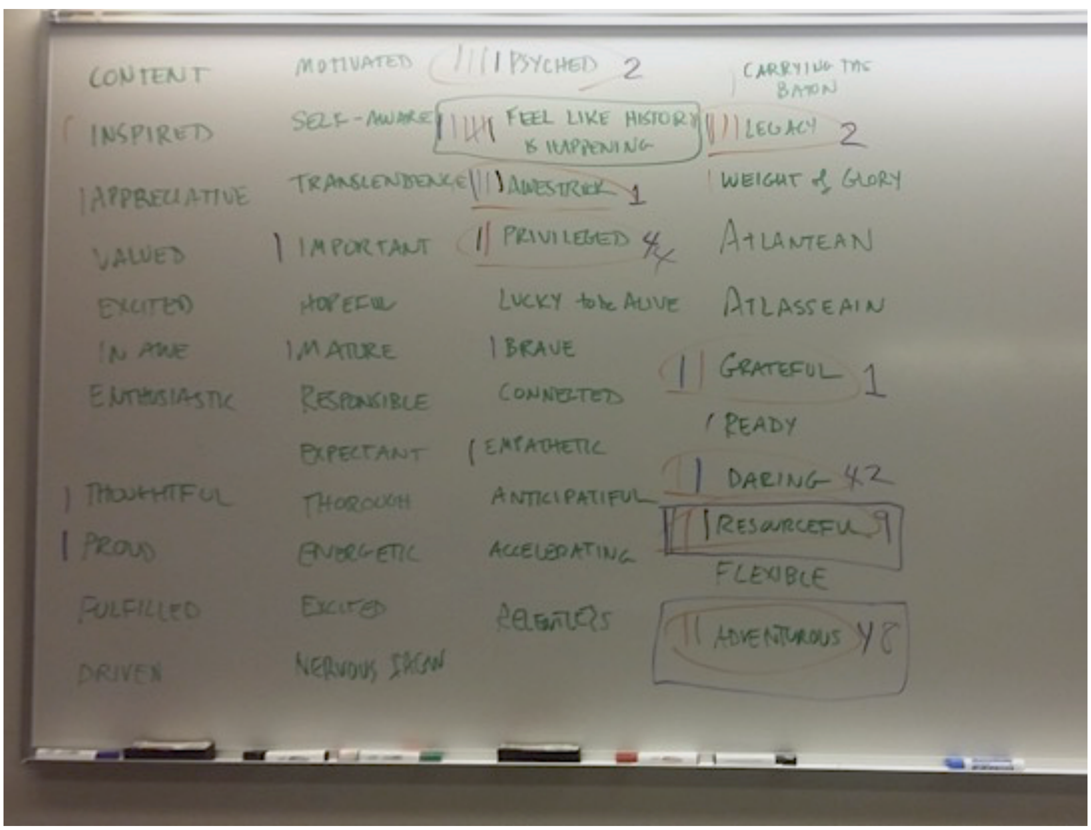

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