ASTEROID (16) PSYCHE: VISITING A METAL WORLD. L.T. Elkins-Tanton[1], E. Asphaug[2], J.F. Bell III[2], D. Bercovici[3], B.G. Bills[4], R.P. Binzel[5], W.F. Bottke[6], M. Brown[4], J. Goldsten[7], R. Jaumann[8], I. Jun[4], D.J. Lawrence[7], P. Lord[10], S. Marchi[6], T. McCoy[9], D. Oh[4], R. Park[4], P.N. Peplowski[7], C.A. Polanskey[4], D. Potter[10], T.H. Prettyman[11], C.A. Raymond[4], C.T. Russell[12], S. Scott[10], H. Stone[4], K.G. Sukhatme[4], N. Warner[4], B.P. Weiss[5], D.D. Wenkert[4], M. Wieczorek[13], D. Williams[2], M.T. Zuber[5]. [1]School of Earth and Space Exploration, Arizona State University, 781 Terrace Rd., Tempe AZ 85287, ltelkins@asu.edu, [2]ASU, [3]Yale, [4]JPL, [5]MIT, [6]SwRI, [7]APL, [8]DLR, [9]Smithsonian, [10]Space Systems Loral, Palo Alto CA, [11]PSI, [12]UCLA, [13]Observatoire de la Côte d'Azur, France.

The Psyche mission has been selected as the fourteenth in the NASA Discovery program. This mission will investigate what is likely an exposed planetary metallic core, the asteroid (16) Psyche.

Estimates of density range widely but include 6,980 ± 580 kg m^{-3} [1], 6,490 ± 2,940 kg m^{-3} [2, 3], and 7,600 ± 3,000 kg m^{-3} [4]. Any density higher than 3,500 kg m^{-3} likely indicates metal: other main belt asteroids have average densities of 1,380 kg m^{-3} for C-type and 2,710 kg m^{-3} for S-type asteroids, roughly one-third to one-half their parent rock density [5].

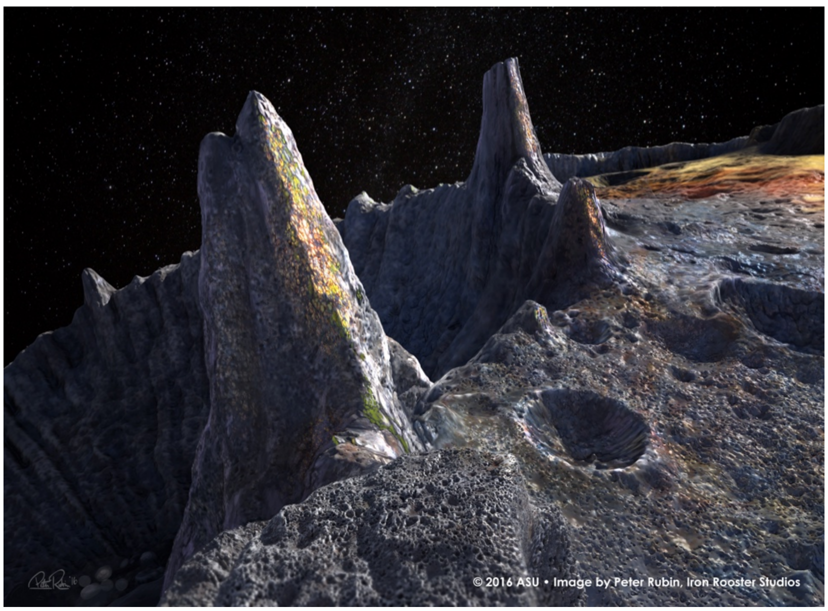

***Fig 1:** Physically plausible geologic processes may have created a landscape at Psyche unlike anything explored before. (Rendering by Peter Rubin).*

Models show that among the accretionary collisions early in the solar system, some destructive "hit and run" impacts strip the silicate mantle from differentiated bodies [6]. This is the leading hypothesis for Psyche's formation: it is a bare planetesimal core. If our observations indicate that it is not a core, Psyche may instead be highly reduced, primordial metal-rich materials that accreted closer to the Sun.

Orbiting in the outer main belt at ~3 AU, the asteroid (16) Psyche has an effective diameter of ~235 km [7], and is thought to be made almost entirely of Fe-Ni metal [8, 9]. A 0.9 μm absorption feature suggests a few percent of its surface is high-magnesian orthopyroxene [10], and new results indicate hydrous features, likely hydrated silicates from chondritic impactors [11].

The mission has five objectives:

A. Determine whether Psyche is a core, or if it is unmelted material.
B. Determine the relative ages of regions of its surface.
C. Determine whether small metal bodies incorporate the same light elements as are expected in the Earth's high-pressure core.
D. Determine whether Psyche was formed under conditions more oxidizing or more reducing than Earth's core.
E. Characterize Psyche's topography and impact crater morphology.

We will meet these objectives by examining Psyche with three high heritage instruments and radio science:

1. Two block-redundant multispectral imagers (MSL Mastcam heritage) with clear and seven color filters provide surface geology, composition, and topographic information. Lead: J.F. Bell, ASU, with Malin Space Science Systems.
2. A gamma-ray and neutron spectrometer (MESSENGER heritage) determines the elemental composition for key elements (e.g., Fe, Ni, Si, and K) as well as compositional heterogeneity across Psyche's surface. Lead: D.J. Lawrence, APL.
3. Dual fluxgate magnetometers in a gradiometer configuration characterize the magnetic field. Investigation Lead: B.P. Weiss, MIT. Development Lead: C.T. Russell, UCLA.
4. Radio science will map Psyche's gravity field using the X-band telecomm system. Lead: M.T. Zuber, MIT.

The solar-electric propulsion chassis will be built by Space Systems Loral in Palo Alto, California [12], the mission will be led by Arizona State University and Jet Propulsion Laboratory will be responsible for mission management, operations, and navigation.

The mission plan calls for 20 months of operations at Psyche. Our operations will closely model those of the Dawn mission at Vesta, including a set of four orbital radii, stepping closer to the body as we better determine the shape and gravity field (Fig. 2).

Synthesis and Expected Outcomes Meteorites reveal that many differentiated bodies, including iron meteorite parent bodies, produced magnetic dynamos [13-15]. High-energy impacts were ubiquitous in the early solar system, so cores likely formed and reformed repeatedly.

If our magnetometer detects a field, then Psyche is a core, had a core magnetic dynamo and solidified outside-in, allowing the cold solid exterior to record the magnetic field [16]. We will then have detected in situ magnetization at an asteroid for the first time. Assuming that Psyche formed as a fractionating core solidifying from the outside-in, we would expect to find surface Ni content of ~4 wt% (or slightly lower if diluted with other material). Nickel of 6–12 wt% indicates the surface was the last material to solidify and thus the core solidified inside-out. We would expect no remanent magnetic field, since there would have been no cool surface material to record the field while the dynamo was working.

If we find very low nickel content, and no coherent magnetic field, then we may arrive at perhaps the most exciting hypothesis: Psyche never melted, but consists of highly reduced, primordial metal. This hypothesis would be further supported by the discovery of no mantle silicates, but instead reduced silicates mixed on a small scale throughout the surface. The likeliest place for such material to exist is closest to the Sun in the early disk, where temperatures are very hot (reducing) and light elements might have been volatilized away, leaving heavy elements and metals [17].

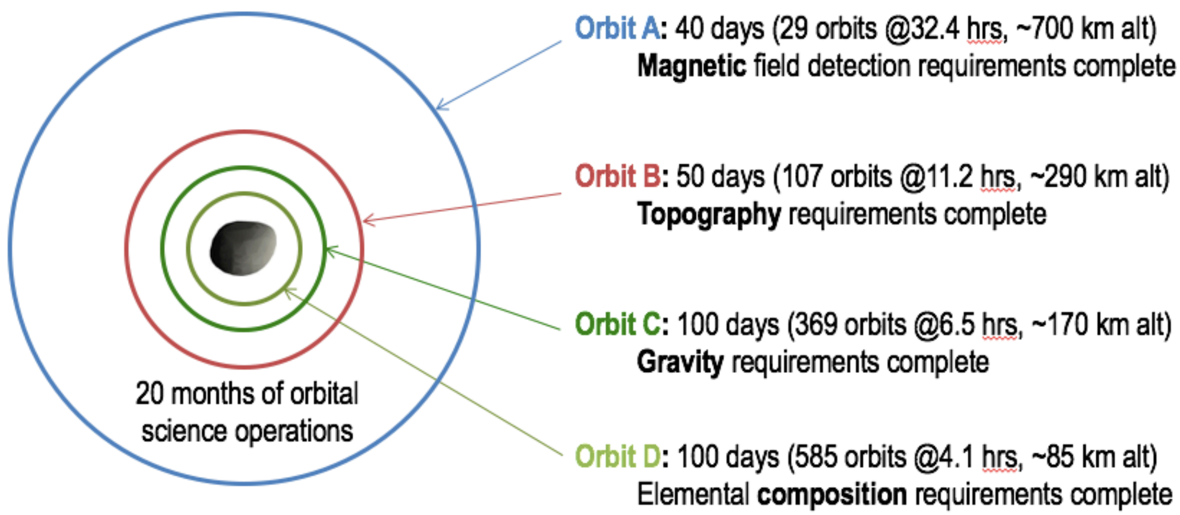

Fig. 2. *Like Dawn, Psyche's science profile uses orbits that progressively improve data quality as knowledge of the gravity field allows lower altitudes (orbit-transfer durations not shown). The spacecraft will orbit Psyche for 20 months.*

[1] Kuzmanoski, M. and A. Koračević (2002) Astronomy and Astrophysics, 395, L17-L19. [2] Baer, J., et al. (2011) The Astronomical Journal, 141, 1-12. [3] Lupishko, D. F. (2006) Solar System Research, 40, 214-218. [4] Shepard, M. K., et al. (2008) Icarus, 195, 184-205. [5] Krasinsky, G. A., et al. (2002) Icarus, 158, 98-105. [6] Asphaug, E. and A. Reufer (2014) Nature Geoscience, 7, 564-568. [7] Shepard, M. K., et al. (2017) Icarus, 281, 388-403. [8] Shepard, M. K., et al. (2010) Icarus, 208, 221-237. [9] Matter, A., et al. (2013) Icarus, 226, 419-427. [10] Hardersen, P. S., et al. (2005) Icarus, 175, 141-158. [11] Takir, D., et al. (2016) The Astronomical Journal, 153, 31-37. [12] Oh, D., et al. (2016) AIAA-2016-4541. [13] Tarduno, J. A., et al. (2012) Science, 338, 939-942. [14] Elkins Tanton, L. T., et al. (2011) Earth and Planetary Science Letters, 305, 1-10. [15] Bryson, J. F. J. (2015). [16] Scheinberg, A., et al. (2016) Journal of Geophysical Research, 121, 2-20. [17] Bottke, W. F., et al. (2006) Nature, 439, 821-824.