The Psyche Multispectral Imager Investigation: Characterizing the Geology, Topography, and Compositional Properties of a Metallic World. J.F. Bell III[1], L.T. Elkins-Tanton[1], C. Polanskey[2], M.A. Ravine[3], M.A. Caplinger[3], E. Asphaug[1], D. Bercovici[4], B. Bills[2]; R.P. Binzel[5], W. Bottke[6], R. Jaumann[7], S. Marchi[6], R.S. Park[2], C.A. Raymond[2], D. Wenkert[2], M. Wieczorek[8]; B. Weiss[5], M. Zuber[5]; [1]Arizona State Univ., School of Earth & Space Exploration, Tempe AZ; [2]JPL/Caltech, Pasadena CA; [3]Malin Space Science Systems, Inc., San Diego CA; [4]Yale Univ., New Haven CT; [5]Massachusetts Institute of Technology, Cambridge MA; [6]Southwest Research Inst., Boulder CO; [7]DLR/Inst. of Planetary Research, Berlin, Germany; [8]CNES/Inst. de Physique du Globe de Paris, Paris, France.

Introduction: The Psyche Discovery mission [1] would conduct the first detailed, *in situ* exploration of a metallic world. Asteroid 16 Psyche, the largest of the metal asteroids (> 200 km diameter), is hypothesized to either be the exposed core of a pre-existing larger differentiated body, or composed of primordial material having accreted from highly reduced metal-rich material [2]. The Psyche orbital mission was selected for a Phase A study in the most recent Discovery mission competition, and if selected for flight it would launch in late 2020 and arrive at Psyche (in the Main Belt at ~3 AU heliocentric distance) in early 2026. A key payload element required for answering the science goals and objectives of the Psyche mission [1] is a visible to short-wave near-IR multispectral imager, which will acquire data needed to characterize the shape, topography, geology, and (to a limited extent) surface compositional variations of 16 Psyche. Here we describe the specific science goals, measurement requirements, and planned capabilities of the Psyche Multispectral Imager (PMI) Investigation.

Psyche Imaging-Related Science Goals: A major goal of the Psyche mission is to determine whether Psyche is a differentiated core or if it is primordial unmelted metal. To do that, we need to be able to assess the homogeneity of mixing of silicates and metals on the object. Thus, to aid with this assessment, a major objective of PMI is to image the surface at key wavelengths (Table 1) and at high enough spatial resolution (≤ 500 m/pix) and Signal-to-Noise Ratio (SNR ≥ 50) to enable (a) the metal-to-silicate fraction to be mapped and quantitatively estimated; and (b) diagnostic S-bearing phases like oldhamite [(Ca,Mg,Fe)S] and/or troilite (FeS) to be detected. Additionally, higher-resolution (≤ 20 m/pix) images of the landforms on Psyche and topographic mapping of the surface (from digital terrain models with ≤ 70 m vertical resolution) will enable lower spatial resolution gravity field and neutron/gamma-ray compositional measurements [3] to be correlated with surface geology, providing further insights into internal structure and homogeneity.

Another major goal of the mission is to characterize the relative ages of Psyche's surface regions. PMI will contribute to this goal by enabling the mapping of statistically-significant numbers of impact craters across ≥ 30% of the asteroid's surface at ≤ 20 m/pix and ≥ 50% of the asteroid's surface at ≤ 200 m/pix, also enabling the crustal implications of the observed simple to complex crater transition to be studied.

A third major Psyche mission goal relevant to imaging is to determine whether Psyche was formed under conditions more oxidizing or more reducing than Earth's core. PMI contributes to this goal by helping to detect the potential presence of oldhamite (Table 1), a key marker mineral useful for testing this hypothesis, since cubic monosulfide phases like this are consistent with highly reducing conditions.

The final Psyche mission goal relevant to imaging is simply to characterize the geology and topography of a never-before-seen kind of object: a metallic world. Does Psyche look like a stony or icy body, or is it radically different from known worlds? How do craters, structural features, and erosional landforms scale to a body of this new material type? Is there geologic evidence for events (*e.g.,* cratering, brecciation, tilting) that could have disrupted or modified the magnetization? These are first-order, pure exploration kinds of questions, and PMI will directly address them by providing clear filter and multispectral imaging that will enable mapping at adequate spatial and vertical (topographic) resolutions needed to understand the details of impact, tectonic, and gradational processes on this unique world.

Table 1. Psyche Multispectral Imager Filters

Band[a]	*λ (nm)*	*Science Objective*
Clear	540 ± 280	Unfiltered CCD for OpNav, topography, and geologic characterization
B	437±50	Asteroid classification and blue component of true color
o	495±25	Search for evidence of oldhamite
v	550±25	Oldhamite continuum and green component of true color
w	700±50	Typical peak reflectance continuum and red component of true color
0.75	750±25	Search for evidence of low-Ca pyroxene
p	948±50	Search for evidence of higher Ca pyroxene band and characterize weak Psyche Earth-based spectral feature
z	1041±90	Search for evidence of olivine

[a]Eight Color Asteroid Survey filter designations [3].

Instrument Details: The Psyche Multispectral Imager system is a compact, low mass, and power efficient pair of redundant CCD imaging cameras, filter wheels, and electronics boxes that represents a low risk, high heritage implementation based heavily on the Mars Science Laboratory (MSL) Mastcam, MAHLI, and MARDI imaging systems developed by Malin Space Science Systems (MSSS) [4-6]. In addition to providing broadband imaging for mission optical navigation purposes, PMI also provides broadband and narrowband imaging for Psyche science (Table 1). The PMI Focal Plane Arrays (FPA) and filter wheel assemblies are the same as MSL/Mastcam. The Digital Electronics Assembly (DEA) is the same as MSL/Mastcam with a parts-upgrade of a Xilinx FPGA to the same model used on the flight OSIRIS-REx Touch-and-Go Camera. The optics includes simple lens changes to MSL/Mastcam needed to meet Psyche spatial resolution requirements.

PMI consists of four components: Two identical 148-mm focal length *f*/1.8 cameras, each consisting of an FPA (1600×1200 pixel Kodak KAI-2020 CCD with 7.4 µm pixel pitch), 8-position filter wheel, and optics/sun shade/cover assembly; and two separate DEA boxes consisting of motor drivers, flash memory, and SDRAM controlled by a Xilinx Virtex-4 FPGA. The onboard DEA hardware and software enable lossless or lossy JPEG compression, windowing, a limited amount of image processing (*e.g.,* background removal and cosmic ray filtering), and storage/manipulation of approximately 4000 full-frame uncompressed images in each camera's flash memory prior to downlink. Each camera uses an actuated cover (same mechanism as the MSL/MAHLI cover [6]) to ensure Sun avoidance. PMI uses exactly the same high-heritage interface to the Psyche spacecraft avionics as MSL/Mastcam.

Operations and Expected Performance: The PMI cameras are fixed-focal length systems providing images with an instantaneous field of view of 0.05 mrad, a field of view of 4.6°×3.4°, and a depth of field from 800 m to infinity. PMI ground sampling distance is 10 m/pix from an altitude of 200 km. PMI's two adjacent cameras are both pointed nadir to the asteroid, with adjacent fields of view (wide axis perpendicular to the flight direction). The purpose of the second camera system is to provide redundancy for mission-critical optical navigation, as was done on the Dawn mission. Stereo imaging is nominally planned to be acquired by using just one camera and operationally acquiring ≥ 3 images of each surface element at nadir and at up to ±20° stereo separation.

We have developed a model of the expected radiance on the focal plane from 16 Psyche, based on vendor data and in-flight performance of the FPA and under conservative imaging assumptions: heliocentric distance of 3.3 AU, albedo 0.12, 45° incidence angle, and a relative ground speed of 120 m/sec. The FPA is passively cooled to space to an equilibrium temperature of < 300K, enabling the low dark current required to meet our imaging SNR requirements. Under such conditions, our model predicts per-pixel SNR ≥ 50 for all images, SNR ≥ 100 at wavelengths of 750 nm and below, and that 2×2 and 3×3 pixel binning yields SNR ≥ 100 for imaging at 948 and 1041 nm, respectively.

To ensure that we will meet our SNR goals, PMI will be radiometrically calibrated to ≤ 10% absolute and ≤ 2% relative (filter to filter) radiance through a pre-flight calibration program to be conducted at MSSS and ASU. Additional calibration will be performed both in system-level testing at MSSS and ASU as well as in JPL and/or Space Systems Loral high-bay testing, using equipment, methods, and algorithms previously developed for MSL/Mastcam [7]. Inflight calibrations will include dark current measurements, images of standard stars and star-clusters for radiometric and geometric validation, and imaging on and off the limb of Psyche for stray light characterization.

Figure 1 shows examples of images of 433 Eros, a large near-Earth asteroid with interesting and diverse geology, at spatial scales like those that we will obtain with PMI during the mission's orbital phases [1]. Craters down to ~100 m diameter and even very large boulders will be recognized and characterized from mapping orbit A, as well as large-scale terrain differences based on albedo, morphology, and crater density. At finer scales, smaller craters become recognizable (down to 20–30 m diameter at 5 m/pix), as do smaller boulders/clusters, and fine details of regolith movement and ridges suggestive of tectonic deformation.

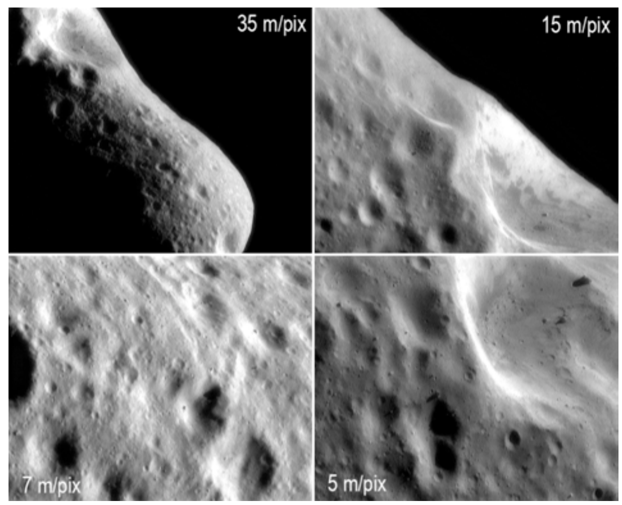

Figure 1. Images of 433 Eros from the NEAR-Shoemaker mission at the pixel scales expected for (clockwise from upper left) the Psyche mission's A, B, C, and D orbits [1].

References: [1] L.T. Elkins-Tanton et al., this *LPSC*, 2016; [2] L.T. Elkins-Tanton et al., *LPSC,* Abstract #1632, 2015; [3] D. Lawrence *et al.,* this LPSC; [3] B. Zellner *et al., Icarus, 61,* 355-416, 1985; [4] M.C. Malin *et al., LPSC 41,* #1123, 2010; [5] J.F. Bell III *et al., LPSC 43,* #2541, 2012; [6] K.E. Edgett *et al., Space Sci. Rev. 170,* 259–317, 2012. [7] J.F. Bell III *et al.,* submitted to *Earth & Space Sci.,* 2016.