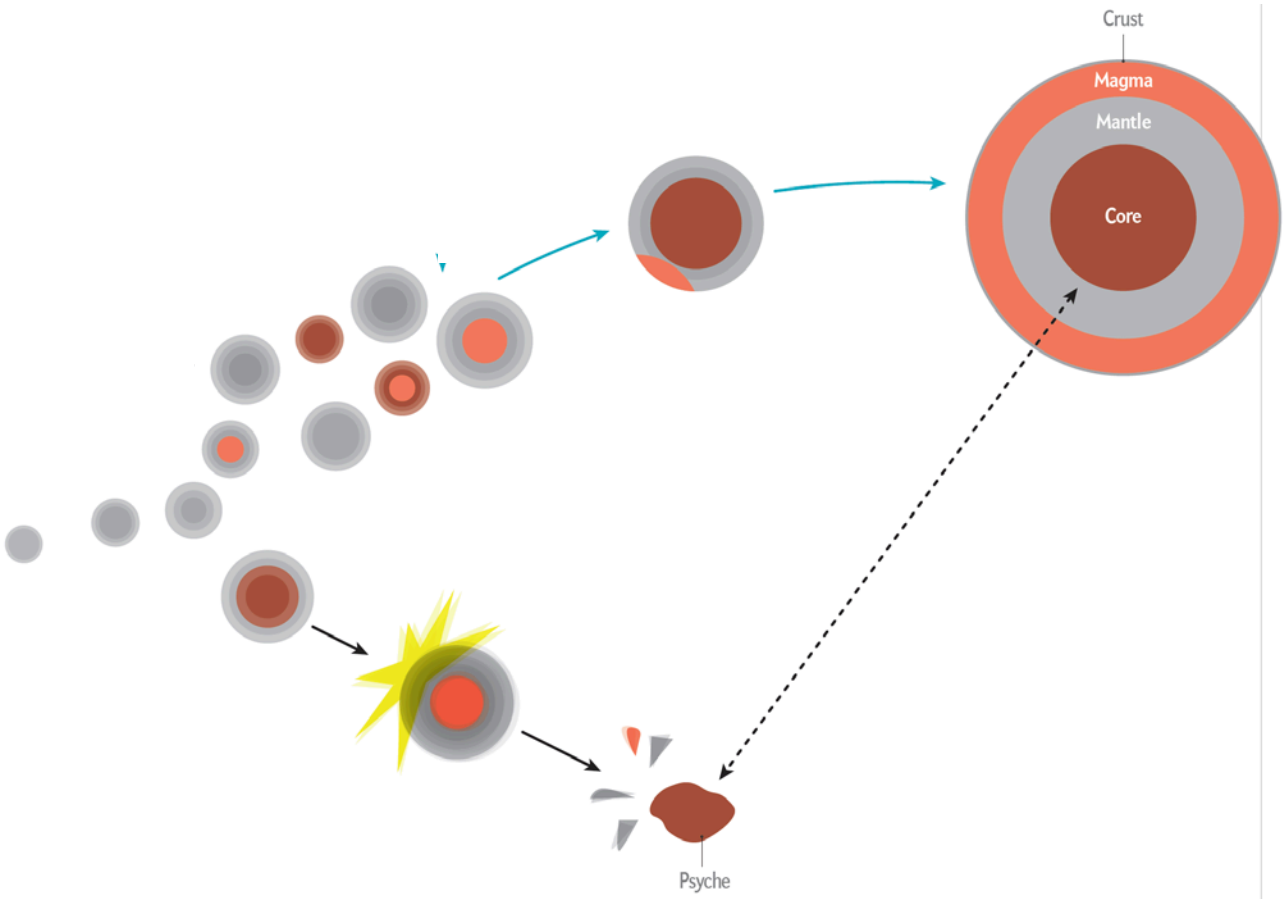
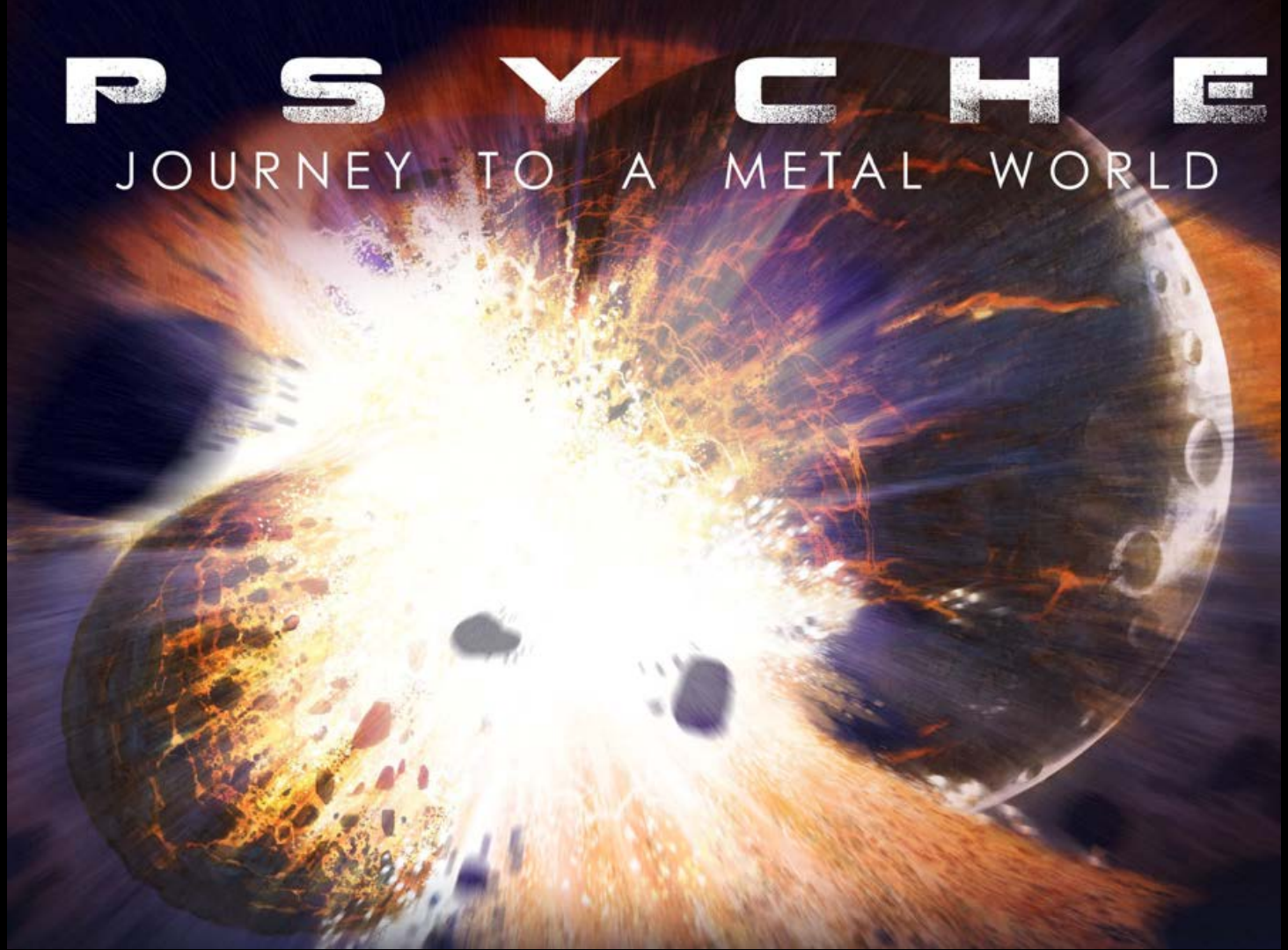
The NASA Psyche Mission


Crust
Magma
Mantle
Core
Psyche


POW!
1.
2.
3.
4.
5.
6.
7.
8.
9.

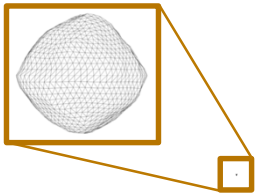

PSYCHE
JOURNEY TO A METAL WORLD


PSYCHE

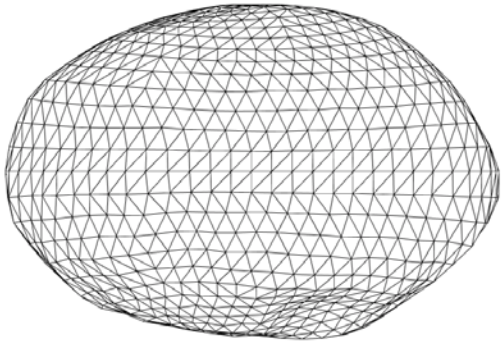
We do not know what Psyche looks like

Image by Patrick Young and Karen Knierman

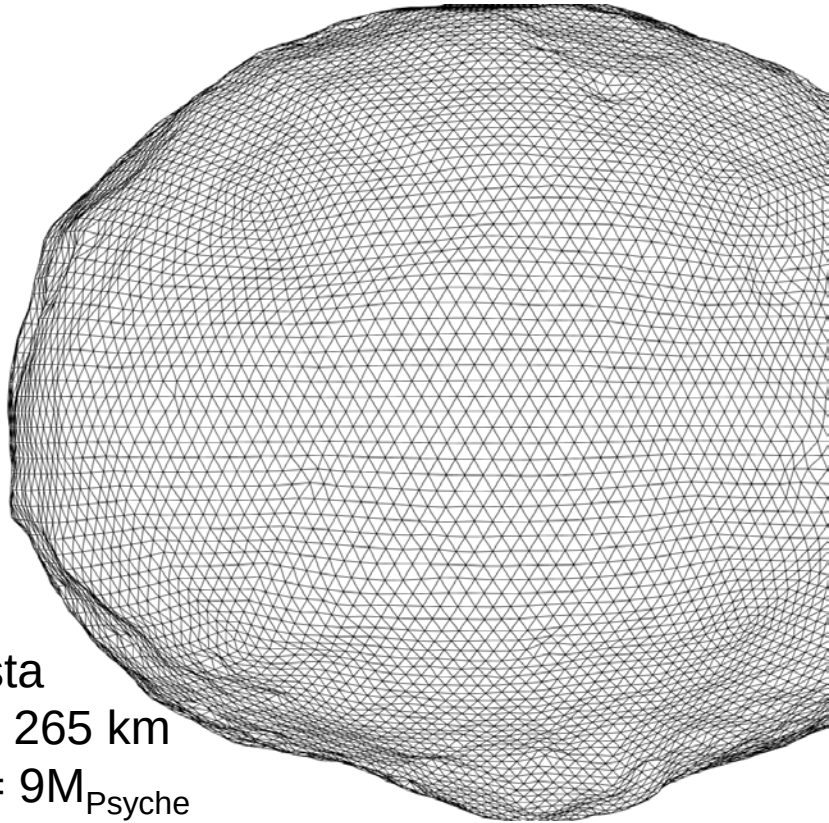
Bennu
R = ~0.25 km
M = (0.000000003)M_{Psyche}



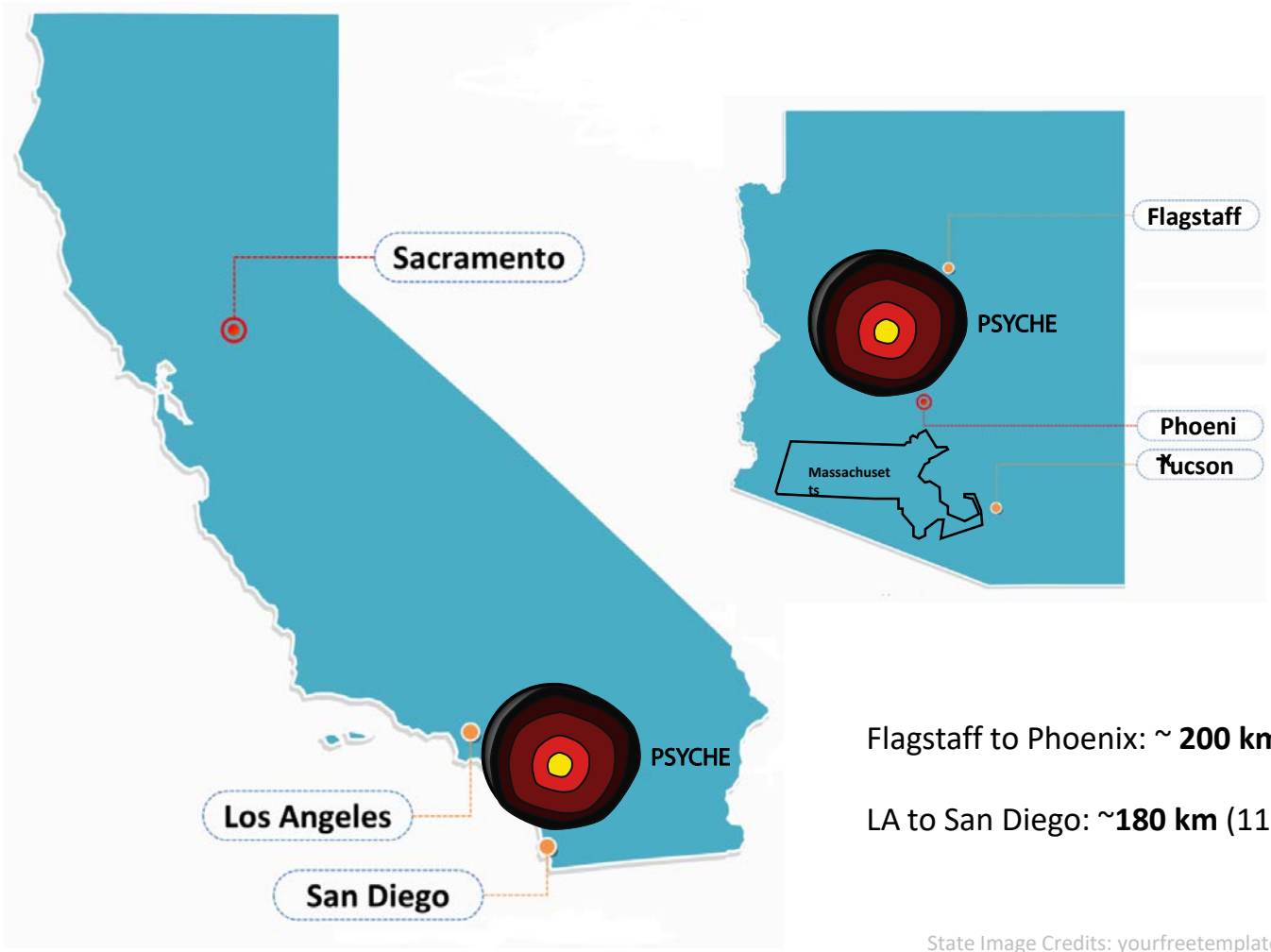
Eros
R = 16 km
M = (0.00024)M_{Psyche}



Psyche
R = 105.5 km



Vesta
R = 265 km
M = 9M_{Psyche}



Flagstaff to Phoenix: ~ **200 km** (124 miles)

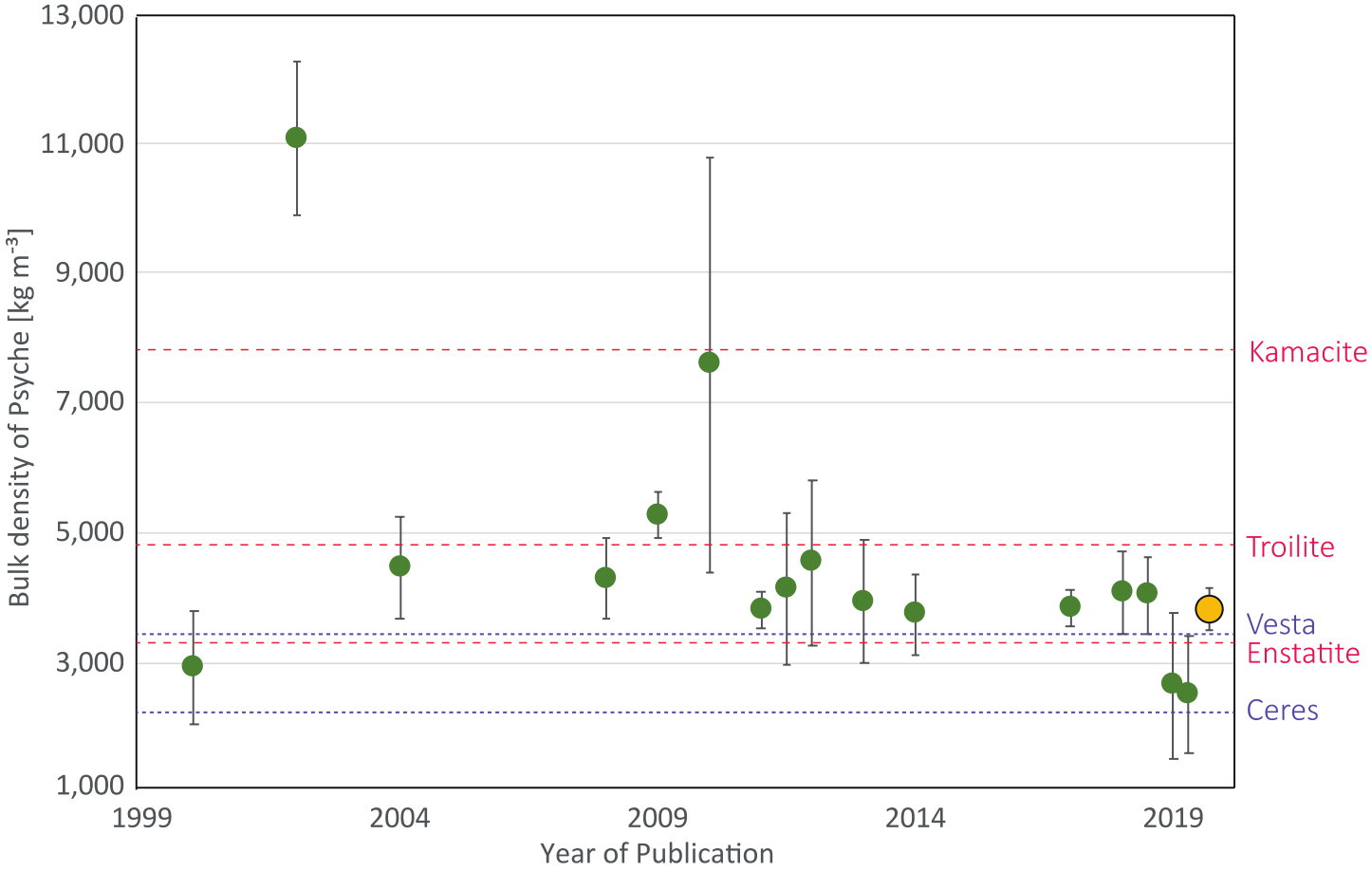
LA to San Diego: ~**180 km** (112 miles)

State Image Credits: yourfreetemplates.com

The fundamental shape model for Psyche is known sufficiently well to have an effective volume agreeing within about 10% for the most recent three estimates at their central values, and with about 30% difference at their one sigma errors.

Effective Diameter (km)	Effective Volume ($\times 10^6$ km^3)	Source
226 ± 23	6.04 ± 1.84	Shepard et al. (2017)
223 ± 7	5.81 ± 0.55	Drummond et al. (2018)
226 ± 5	6.04 ± 0.40	Viikinkoski et al. (2018)

Elkins-Tanton et al. (2020)



Elkins-Tanton et al. (2020)

Quantity	Value		Reference
Thermal inertia ($J\ m^{-2}\ s^{-1/2}\ K^{-1}$)	243 - 284 11 – 53 (Vesta = 30)	Inconclusive; contradictory	Matter et al. (2013) Landsman et al. (2018)
Radar albedo	Disk averages range from values as low as 0.25 to values as high as 0.54 Supportive of metal		Shepard et al. (2018)

Elkins-Tanton et al. (2020)

Observational data interpretations

Psyche's bulk density appears to be between 3,700 kg m^{-3} and 4,200 kg m^{-3}.

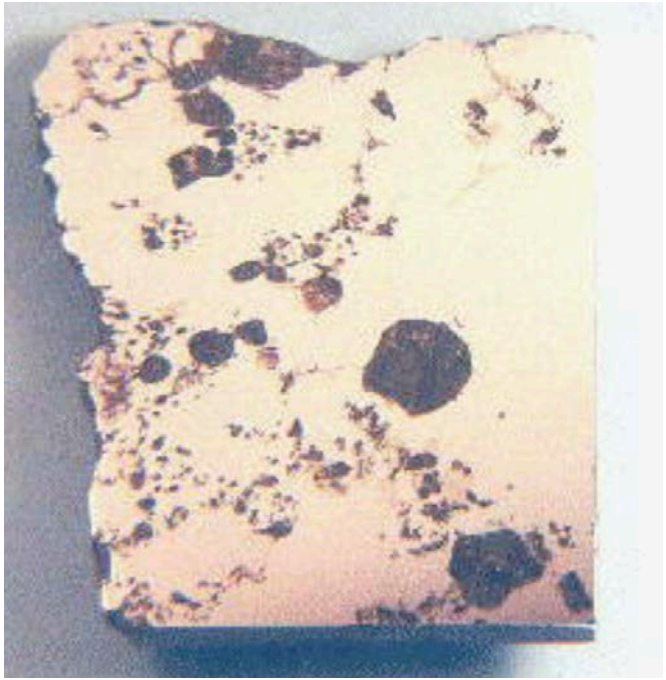
Psyche is predicted to have between ~25 and 60 vol% metal.

The reflectance and optical properties indicate *non-uniquely* that the body may be largely metallic.

The interpretation of a metal surface is supported by density and radar albedo.

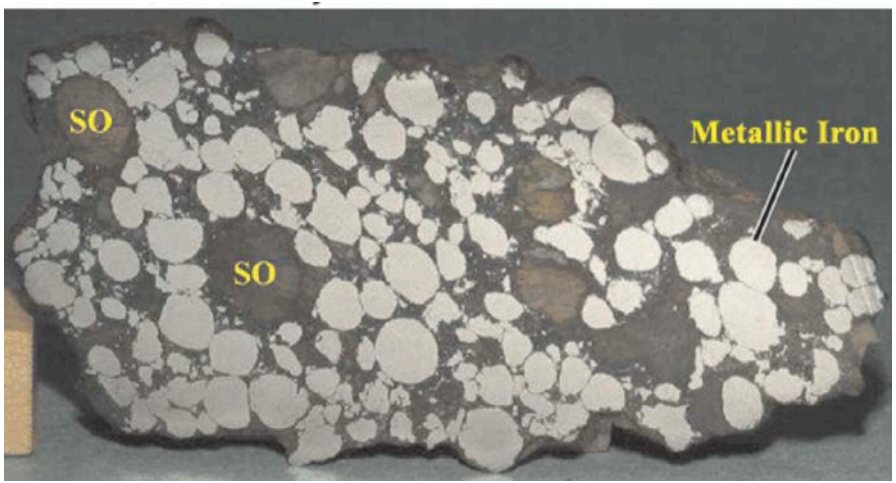
Stony-iron meteorites

Mesosiderite: probably not a candidate
(http://www.arizonaskiesmeteorites.com)



Pyroxene pallasite (Vermillion): a Psyche candidate
http://www.meteoritestudies.com

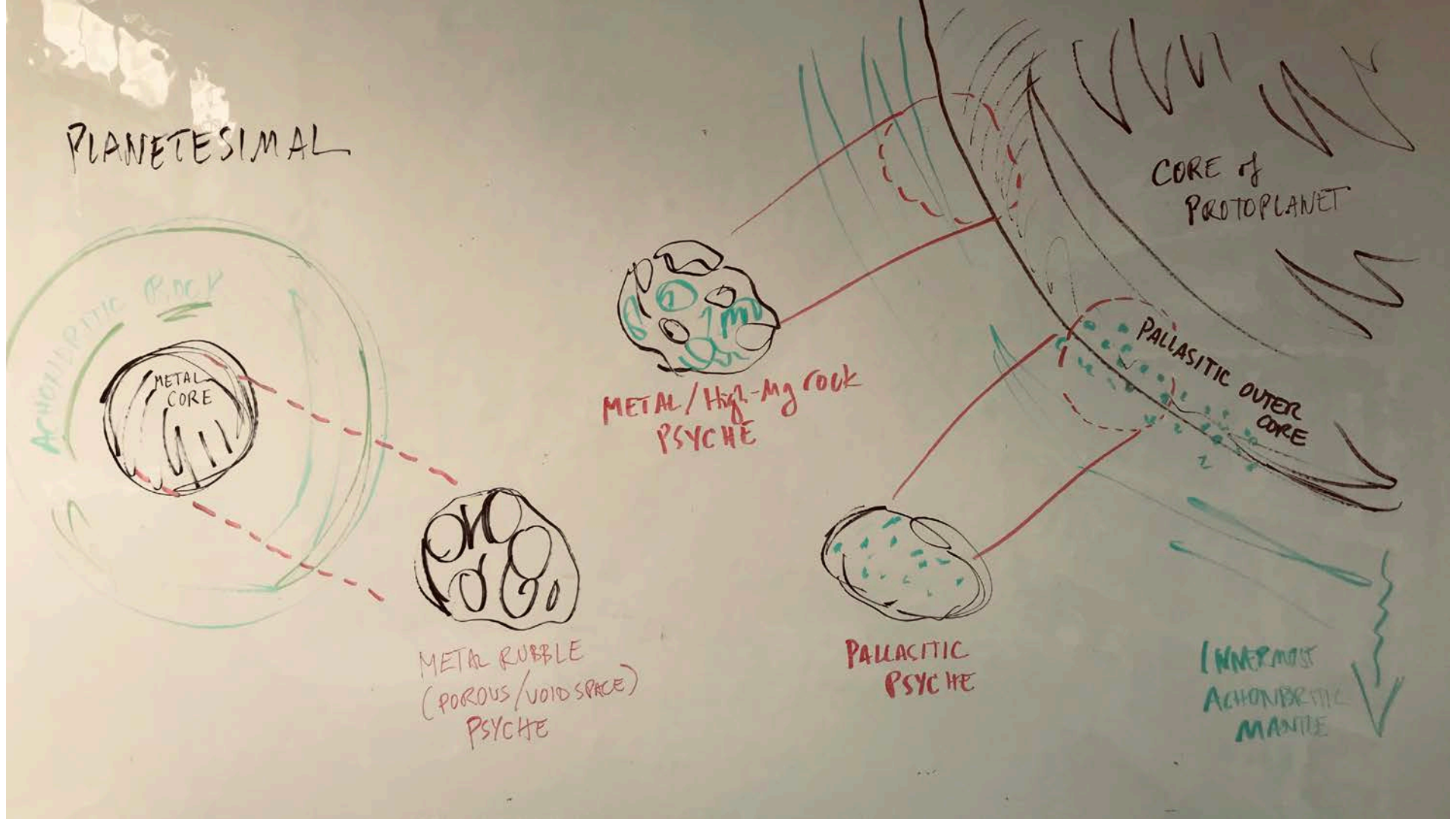
CB chondrites

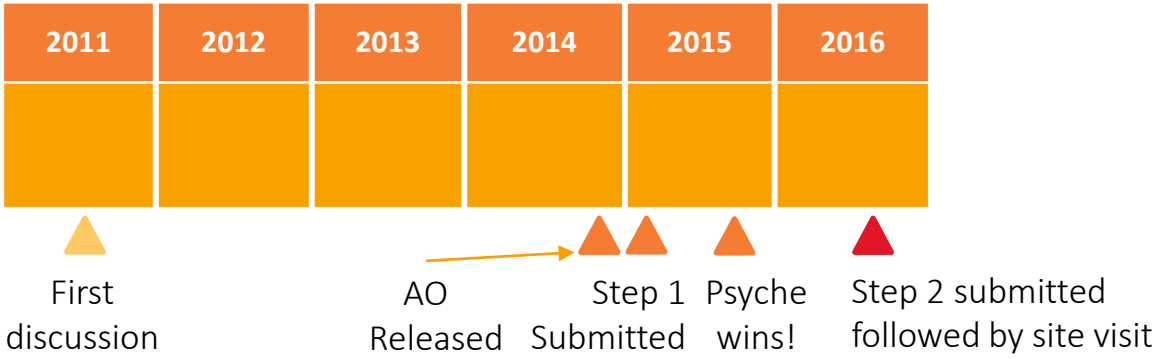


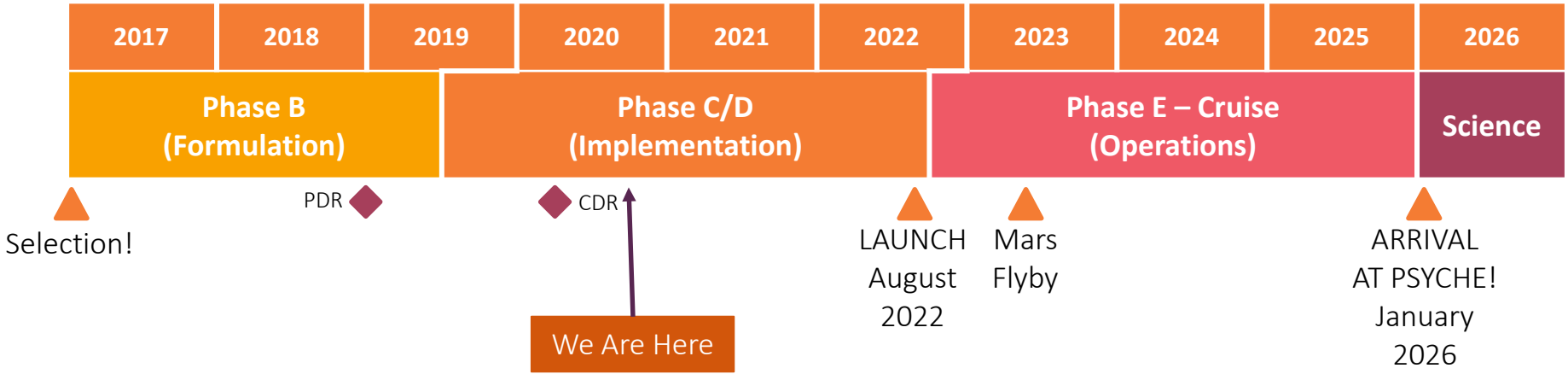
Gujba: A Psyche candidate
(Krot et al., 2005)

Forthcoming data on spectra by
Stephen Dibb and Jim Bell, ASU

Isheyevo: A Psyche candidate
http://www.meteoritestudies.com


PLANETESIMAL
METAL CORE
METAL RUBBLE (POROUS/VOID SPACE) PSYCHE
METAL/High-Mg rock PSYCHE
CORE of PROTOPLANET
PALLASITIC OUTER CORE
PALLACITIC PSYCHE
INNERMOST ACHONDRITIC MANTLE


2011
2012
2013
2014
2015
2016
First discussion
AO Released
Step 1 Submitted
Psyche wins!
Step 2 submitted followed by site visit


2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
Phase B (Formulation)
Phase C/D (Implementation)
Phase E – Cruise (Operations)
Science
Selection!
PDR
CDR
We Are Here
LAUNCH August 2022
Mars Flyby
ARRIVAL AT PSYCHE! January 2026

Science Goals

1. Understand a previously unexplored building block of planet formation: Iron cores

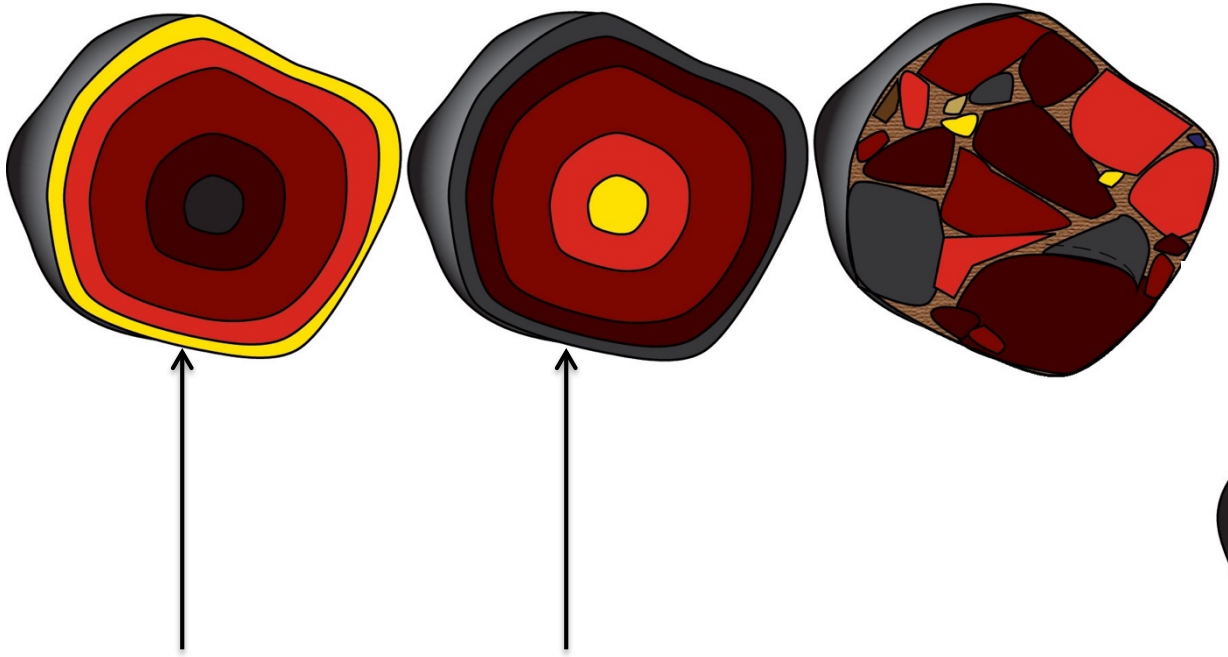
2. Look inside the terrestrial planets, including Earth, by directly examining the interior of a differentiated body, which otherwise could not be seen.

3. Explore a new type of world. For the first time, examine a world made not of rock or ice, but of metal.

Image credit: Christopher Sullivan, Art Institute of Chicago

Objective A: Is Psyche a core?

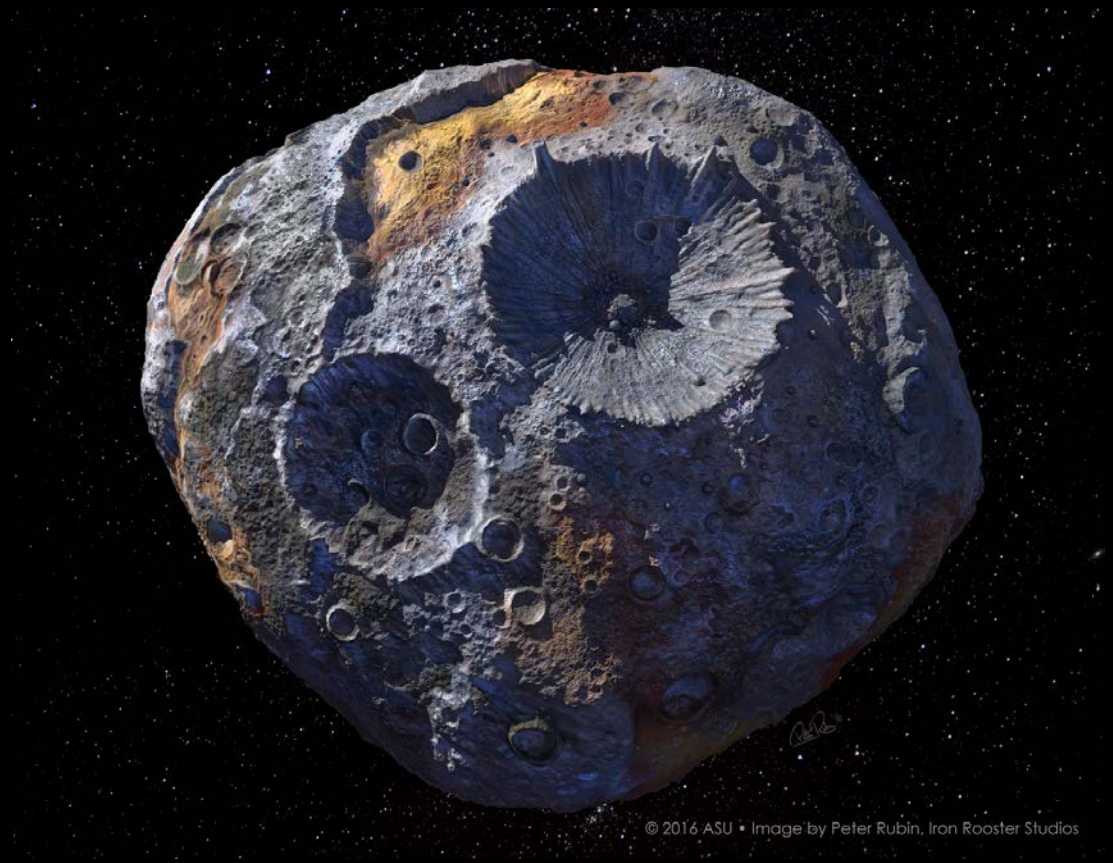
Magnetometer
Imagers
Gravity experiment
GRNS



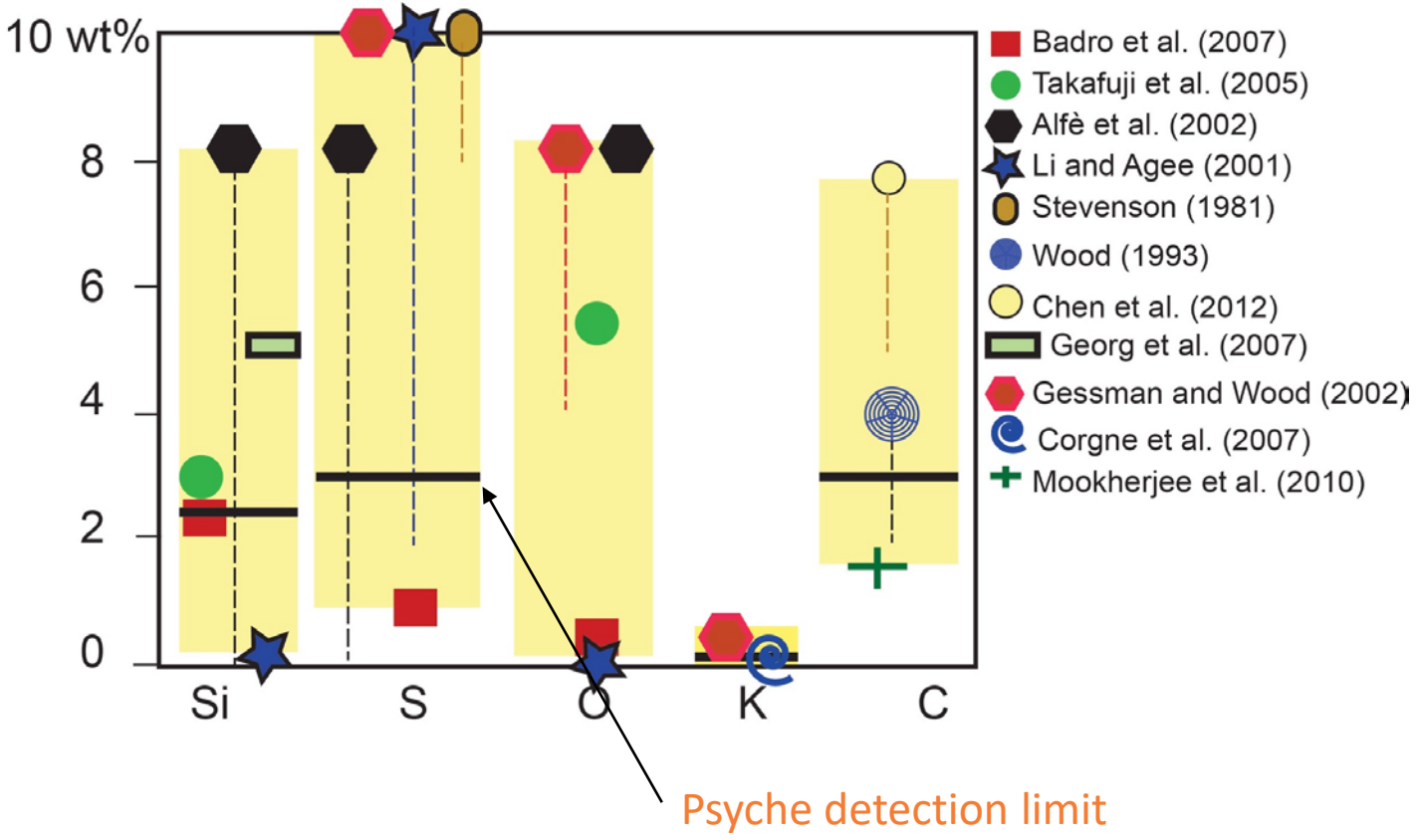
High Nickel

Low Nickel

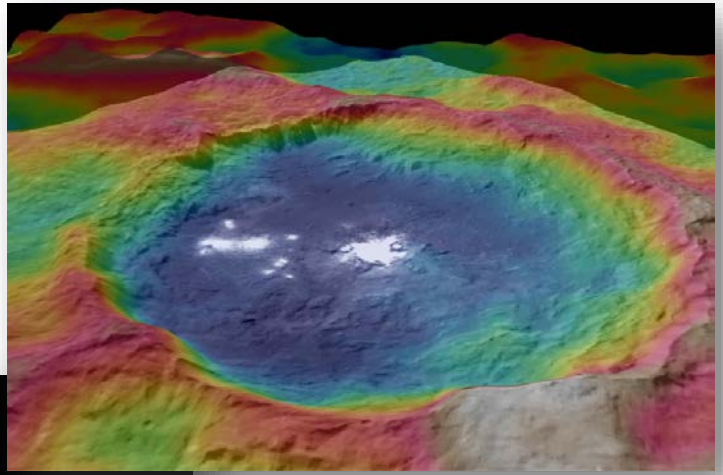
Objective B: Determine the relative ages of surface regions

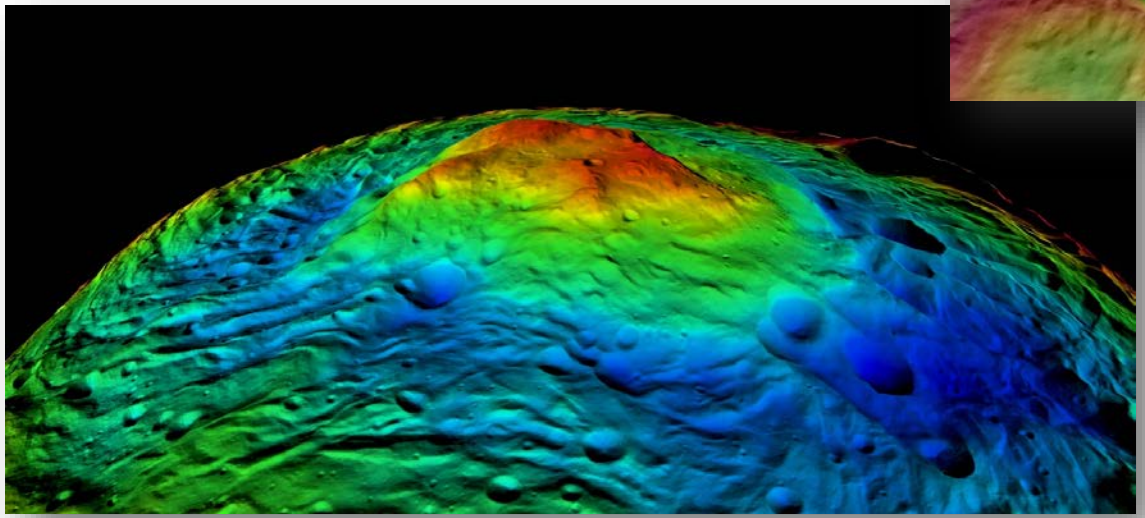


Objective C: Light elements in the core
Objective D: Oxidizing or reducing conditions of core formation



Objective E: Characterize Psyche's morphology



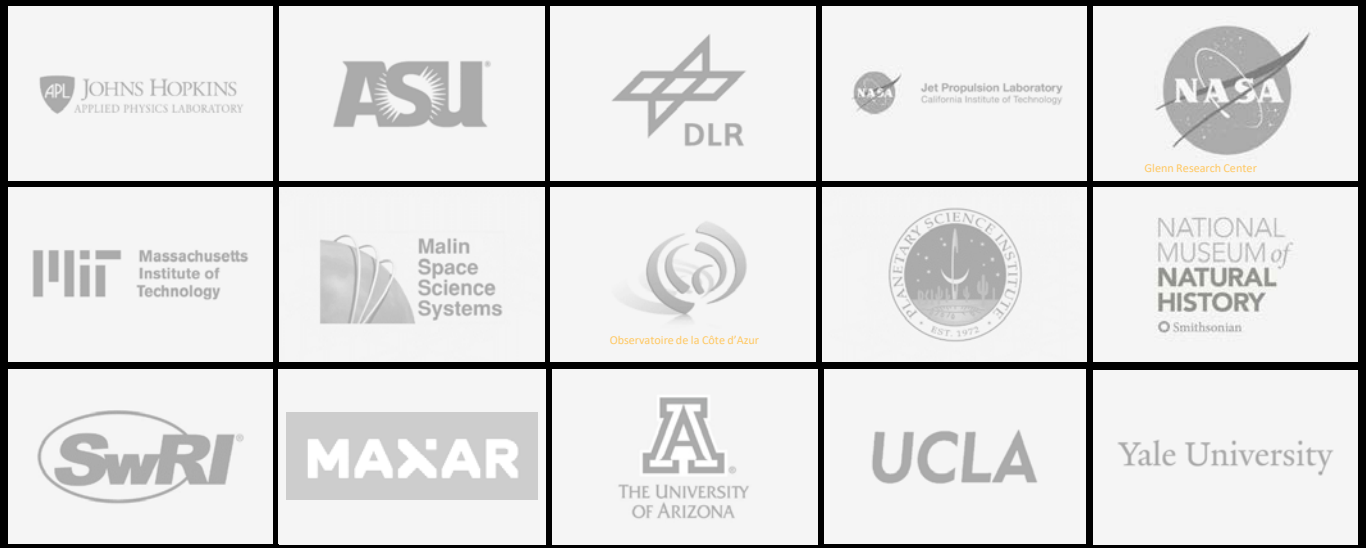


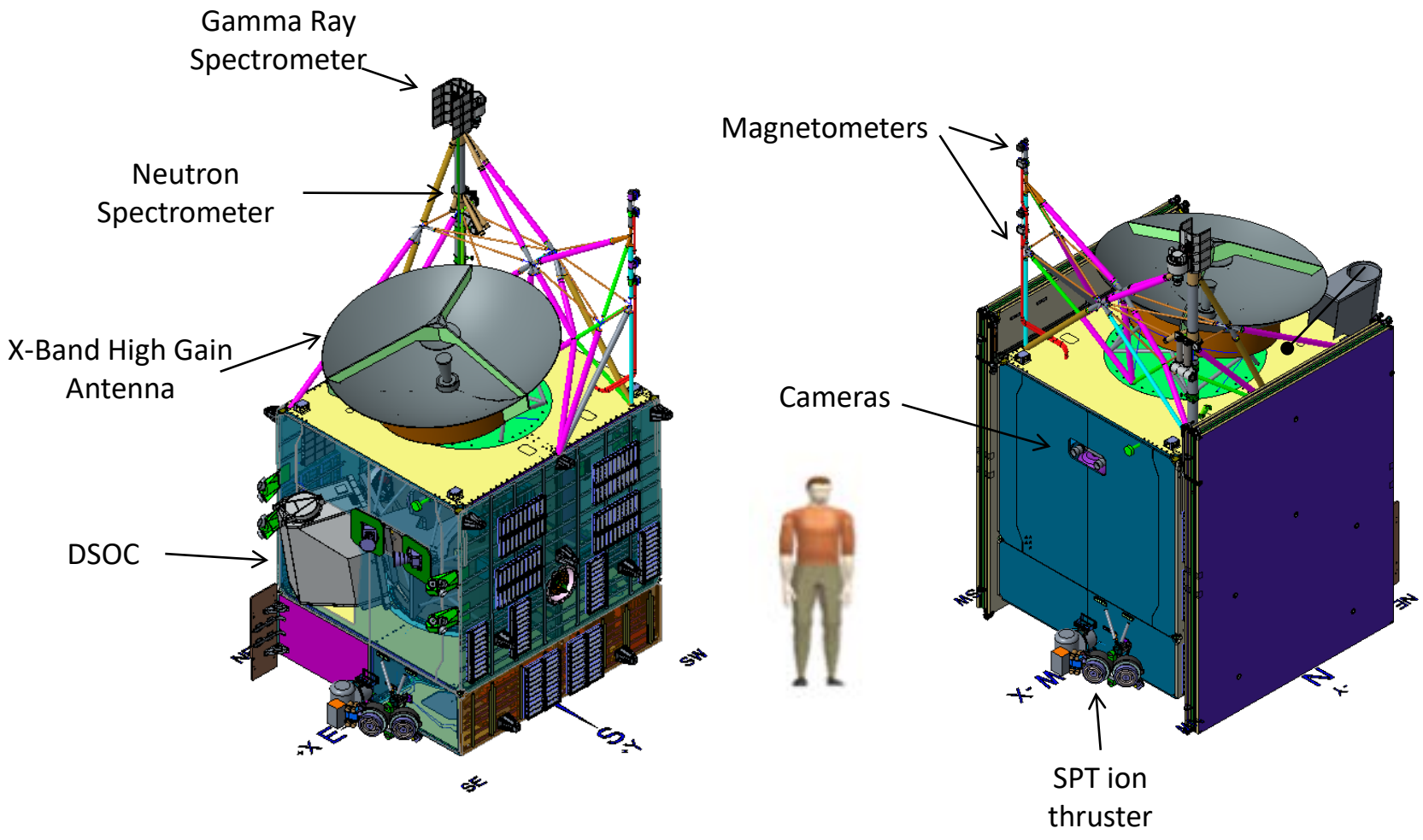
Ceres (top) and
Vesta (bottom)

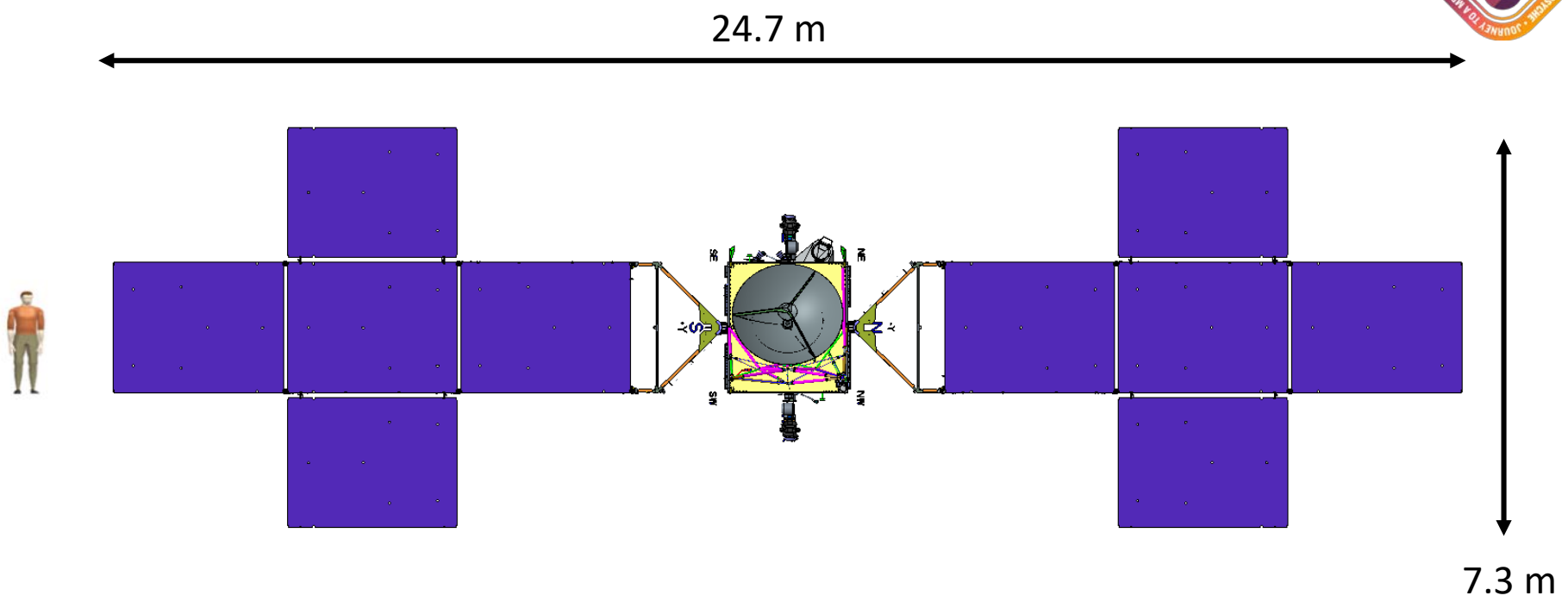
Dawn mission
NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

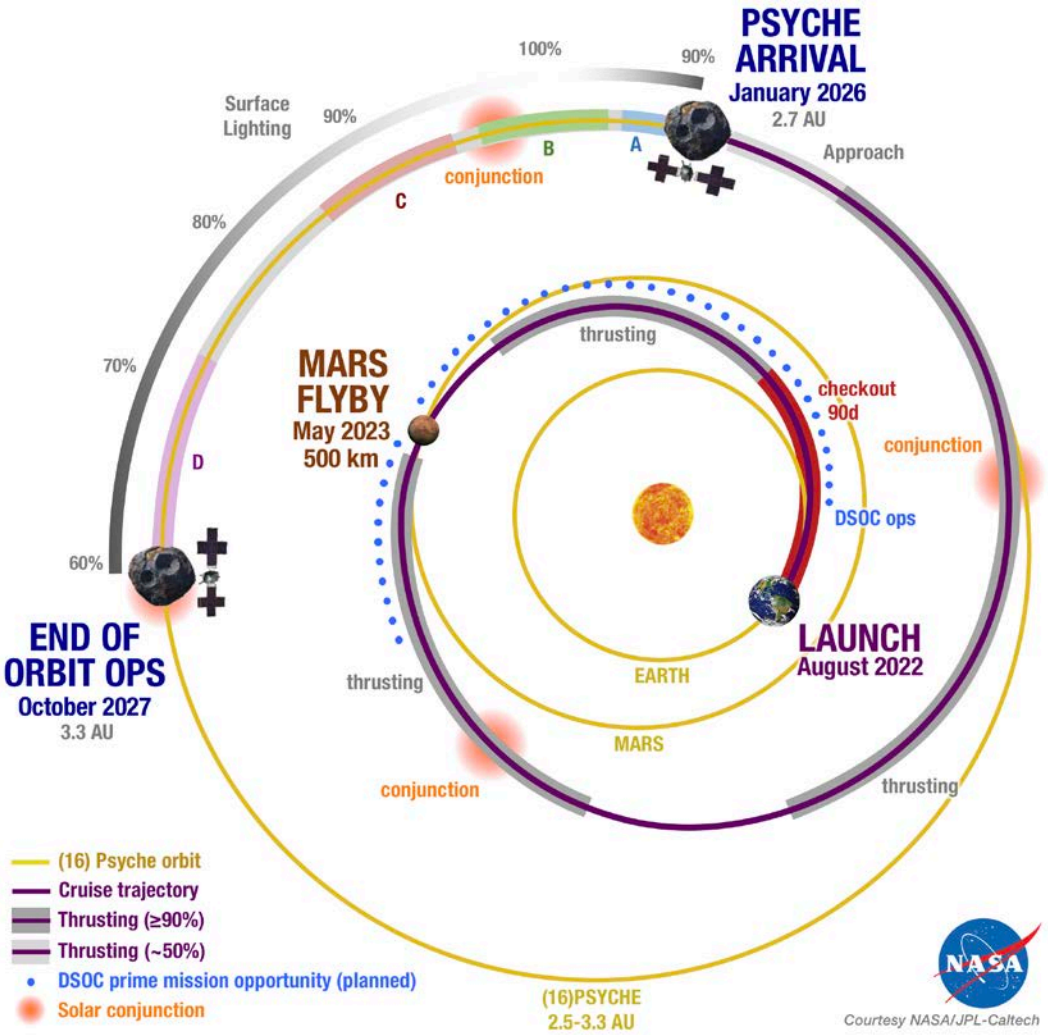
Marchi et al. (2020)

A Sampling Of Psyche's Partner Institutions (It Takes a Village!)




Gamma Ray Spectrometer
Neutron Spectrometer
X-Band High Gain Antenna
DSOC
Magnetometers
Cameras
SPT ion thruster


24.7 m
7.3 m


PSYCHE ARRIVAL
January 2026
2.7 AU
100%
90%
Surface Lighting
90%
80%
70%
60%
Approach
B
A
conjunction
C
D
MARS FLYBY
May 2023
500 km
thrusting
checkout
90d
conjunction
DSOC ops
LAUNCH
August 2022
EARTH
MARS
thrusting
thrusting
conjunction
END OF ORBIT OPS
October 2027
3.3 AU
(16) Psyche orbit
Cruise trajectory
Thrusting (≥90%)
Thrusting (~50%)
DSOC prime mission opportunity (planned)
Solar conjunction
(16)PSYCHE
2.5-3.3 AU
NASA
Courtesy NASA/JPL-Caltech

Sun location during orbit A; Sun rotates to the left as seen from (16) Psyche over time; for Orbit D, Sun is directly left

ORBIT A

700 km alt, 90° inc
56 days = 41 orbits x 32.6 hours each
Magnetic field measurements
Imaging and mapping

ORBIT C

170 km alt, 88° inc
100 days = 362 orbits x 6.7 hours each
Gravity, topography measurements
Continued magnetic measurements

ORBIT B

290 km alt, 90° inc
80 days = 169 orbits x 11.4 hours each
Topography, geologic mapping
Continued magnetic measurements

ORBIT D

85 km alt, 160° inc
100 days = 684 orbits x 3.5 hours each
Composition measurements
Continued gravity, mapping, magnetic measurements

Transitions from Orbit A to B and from B to C are shown in gray; C to D is not shown due to its complexity

Student Collaborations

1. Interdisciplinary capstone projects
2. Psyche Inspired art interns
3. K-12 science interns
4. Innovation Toolkit online courses

Psyche Inspired

Student Collaborations Participants (2017-Present)

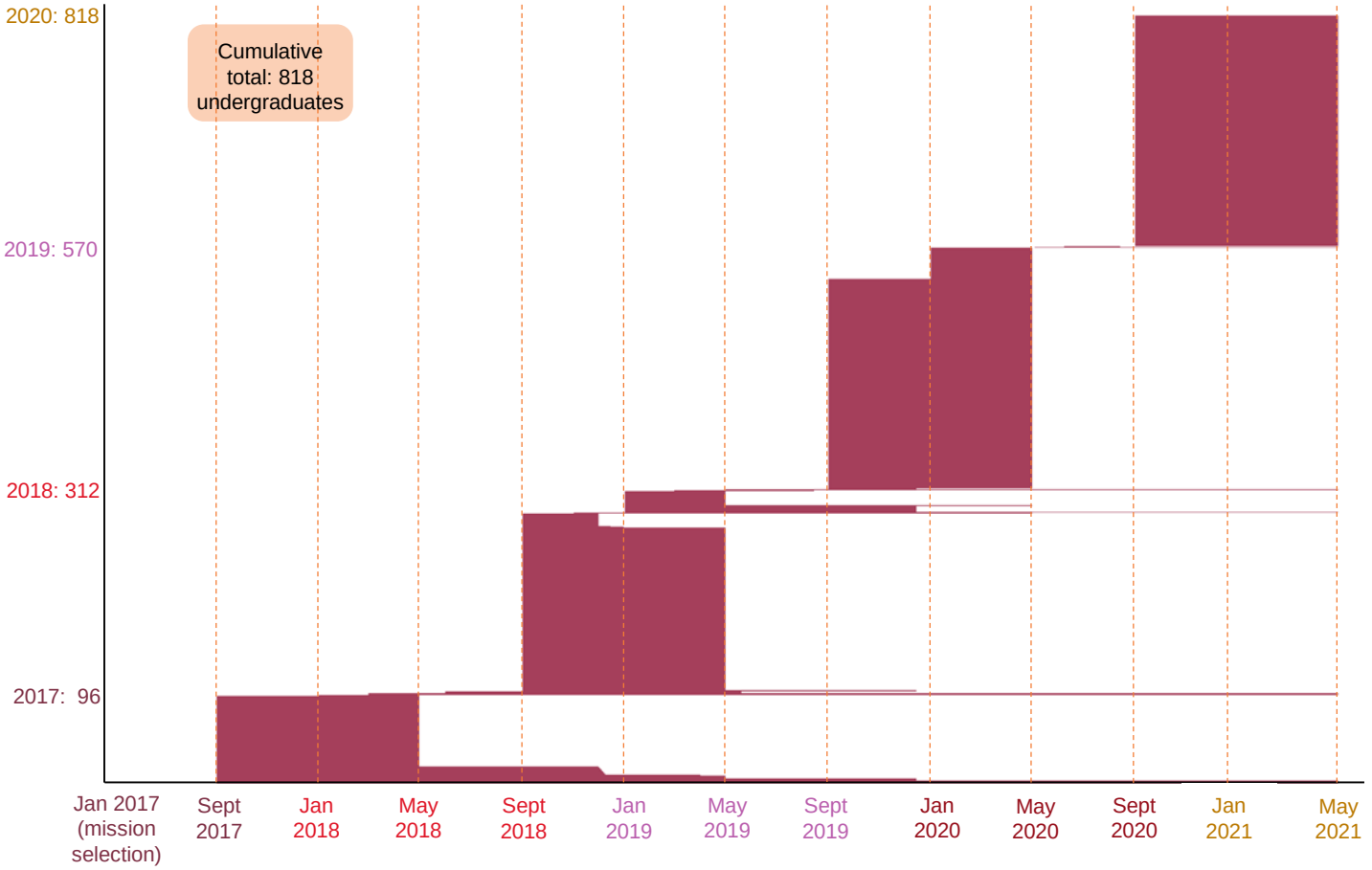
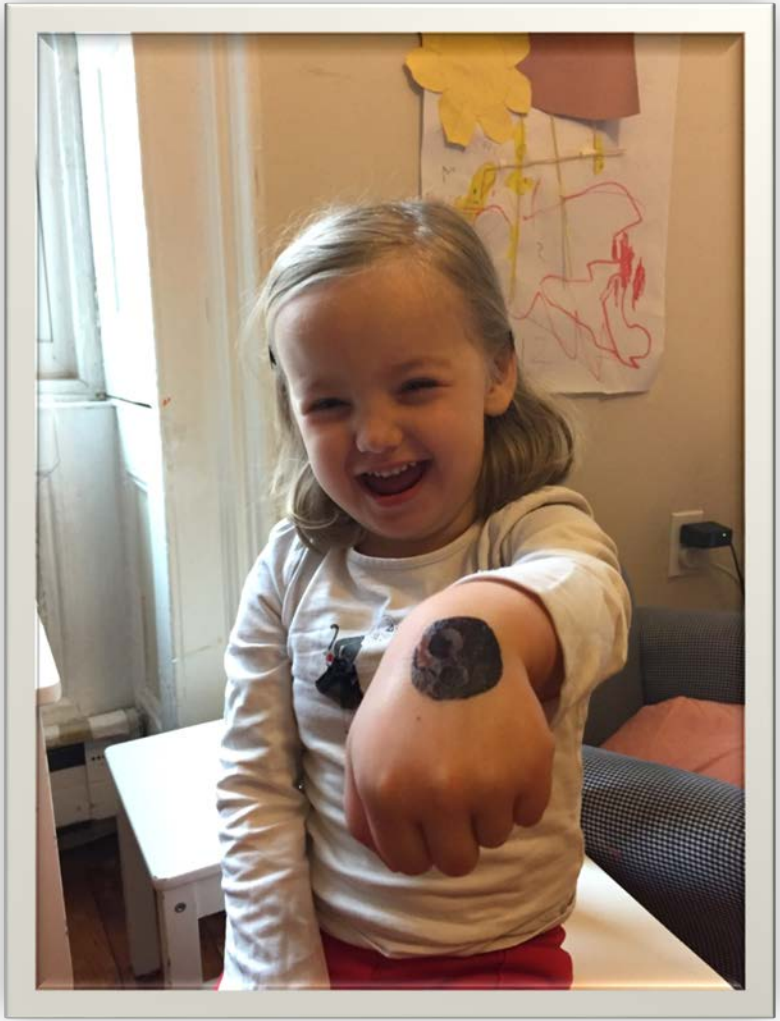


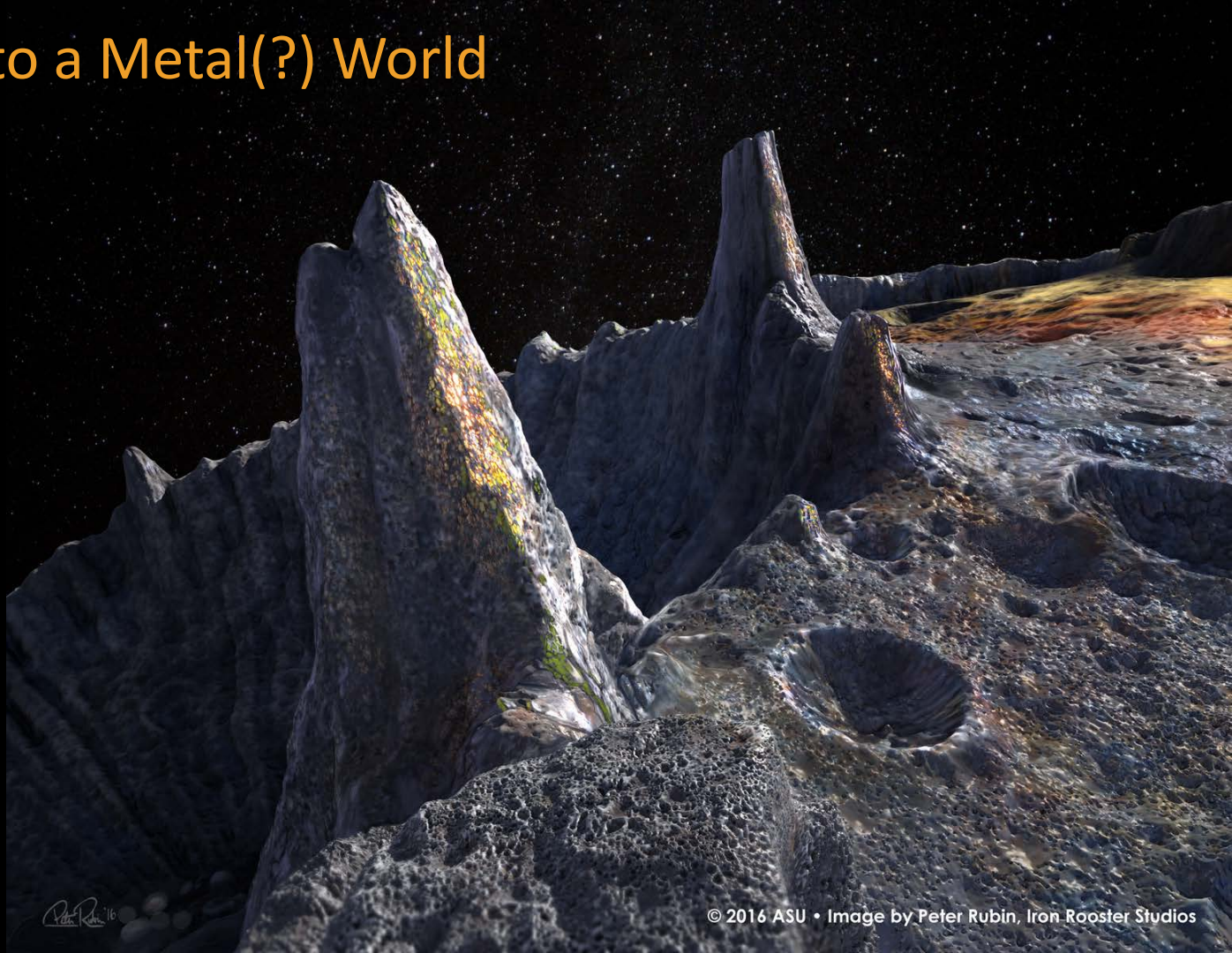
Chart concept credit: R. Binzel

Outreach!

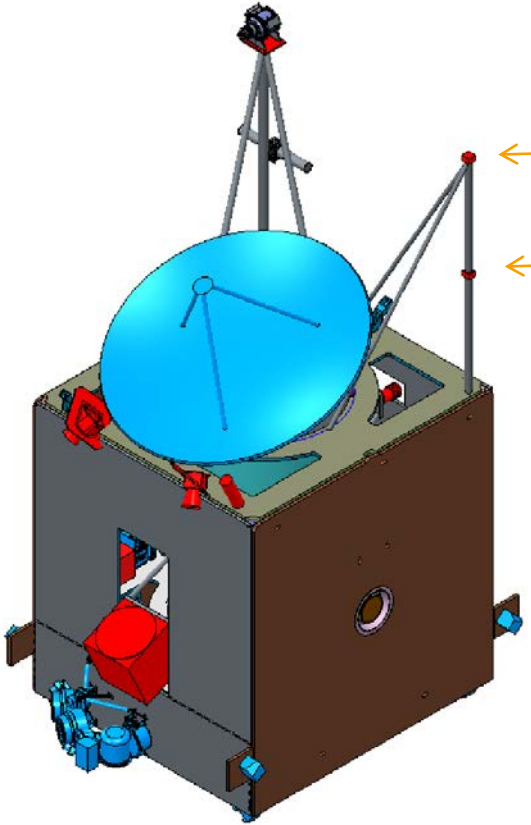


Psyche: Journey to a Metal(?) World

@MissionToPsyche
@ltelkins
https://psyche.asu.edu



So, we need some magnetometers…



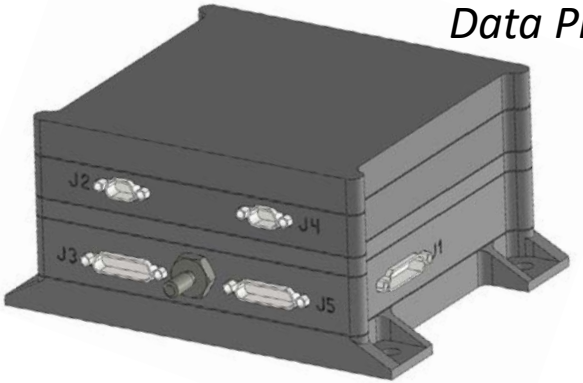
← Sensor 2 @ 1 m

← Sensor 1 @ 2m

CSC cast sensor head

CFRP bracket

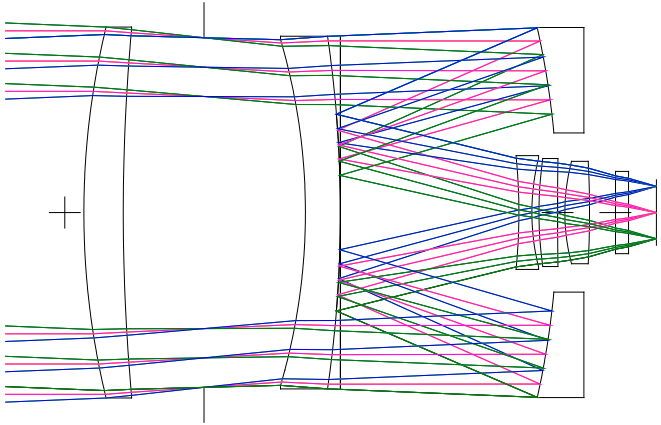
Data Processing Unit



Collaboration of MIT and DTU
Heritage from SWARM, +

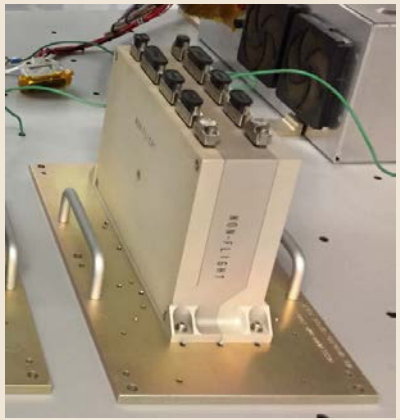
Marchi et al. (2020)

And we need to take great pictures…



Developed by ASU and MSSS, with heritage from MCO, MSL, M2020, +

Two redundant CCD imagers with telescope and 8-position filter wheel



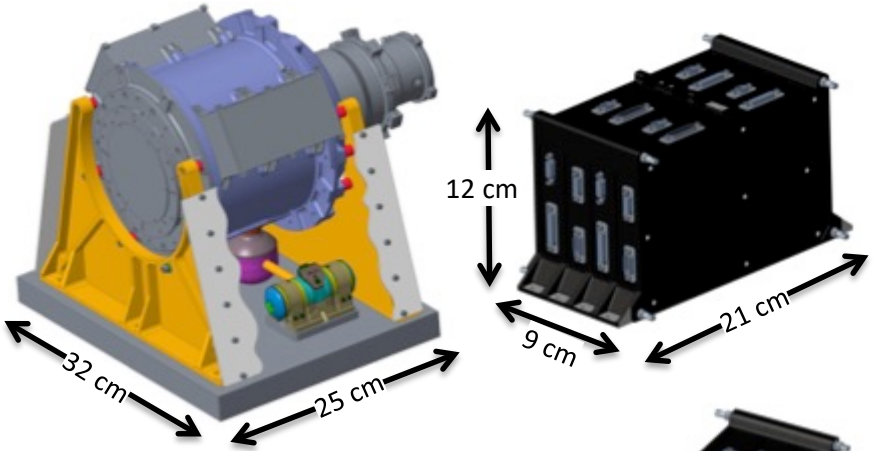
One Digital Electronics Assembly box with two independent cards

Heritage MSL/Mastcam

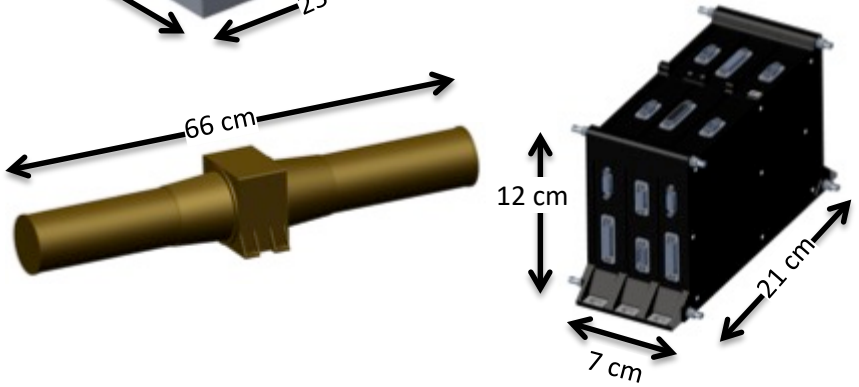
And we need to measure composition…

Psyche Gamma-Ray and Neutron Spectrometer (GRNS)

High-purity Ge crystal gamma-ray spectrometer
Dedicated Data Processing Units



Neutron Spectrometer
Dedicated Data Processing Unit



Developed by JHU/APL
Heritage from MESSENGER, Lunar Prospector, +

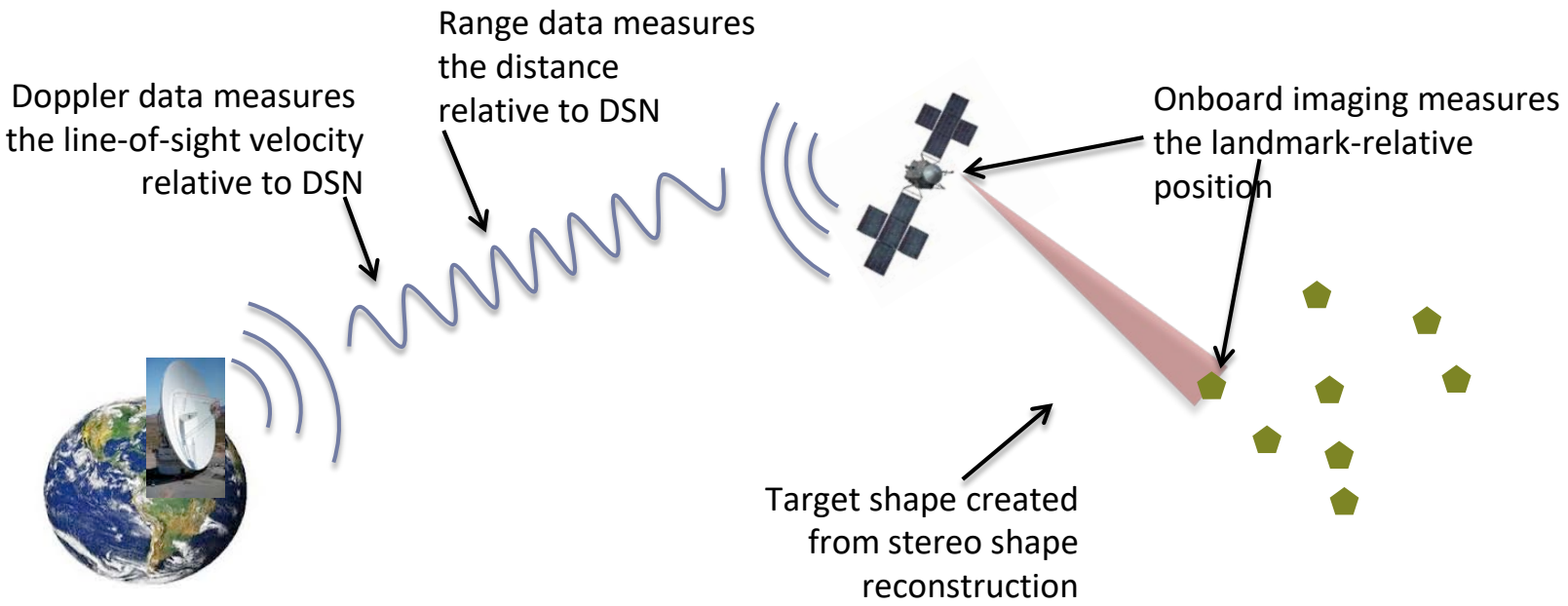
To complete the shape and gravity models…

Psyche Radio Science

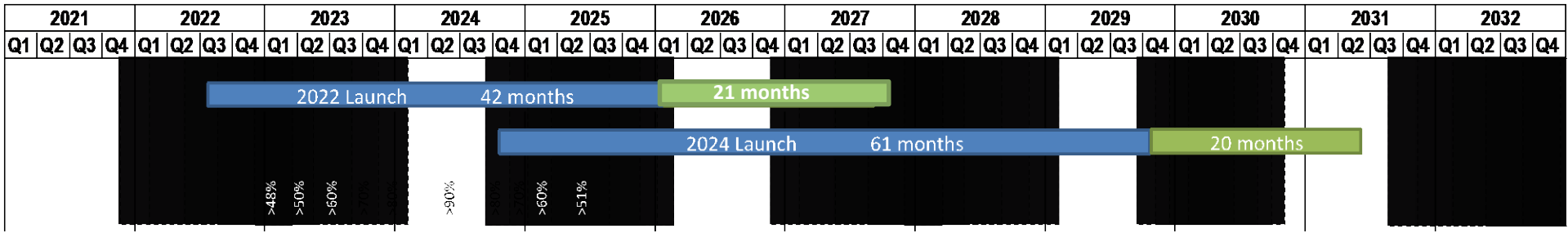
The radio tracking data and onboard imagery determine the **gravity field**, **rotational state**, **topography**, and **ephemeris** of Psyche.

Earth's Deep Space Network to the spacecraft

Spacecraft to Psyche



Developed by JPL+MIT with heritage from Dawn +


2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
Q1 Q2 Q3 Q4
2022 Launch
42 months
21 months
2024 Launch
61 months
20 months
>48%
>50%
>60%
>90%
<60%
<51%