NASA PSYCHE MISSION

Exploration of a Metal World

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Arizona State University

GSA Annual Meeting
Anaheim, CA
Sept. 25, 2024

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Outline

- Asteroids: What and where are they?
  - Why Psyche?
- NASA *Psyche* Mission
  - Objectives of mission
  - Instruments and Operations
  - Launched! October 13, 2023
  - Observations and Expected Results
  - What we've learned about (16) Psyche
- Looking Ahead
- Conclusions and Q&A

Asteroid: Peter Rubin/Caltech-JPL
Spacecraft: SSL

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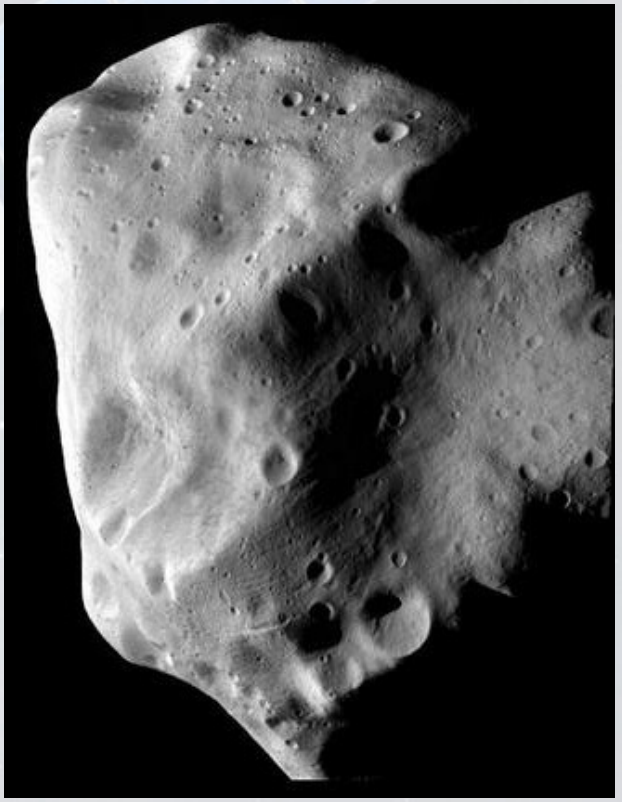
Asteroids

- What are they?
  - Minor planets (protoplanets) w/diameters <500 km
  - Mostly irregularly shaped
  - Mostly composed of silicate rock, dust & volatiles
- Where are they? Mostly *Main Belt*
  - *Main Belt* found between orbits of Mars & Jupiter
  - Lagrange points of Jupiter (*Trojan* asteroids)
  - *Centaurs* occur between orbits of Jupiter & Neptune
  - Near-Earth Asteroids (NEAs) include:
    - *Amor* asteroids (1 AU < q < 1.3 AU)
    - *Apollo* asteroids (q < 1 AU, a > 1 AU)
    - *Aten* asteroids (a < 1 AU)
- There are 14 types of asteroids
  - Classified based on telescopic spectra
  - Largest class: C type (carbonaceous, 40%)
  - S type (stony, 30-35%)
  - D & P types (dark, primitive, 5-10%)
  - M type (metallic – iron), V type (Vesta, unique, basaltic)
- Asteroid spectra compared with meteorites in labs
- Asteroids: rocks that never coalesced into a planet



Asteroid: Peter Rubin/Caltech-JPL

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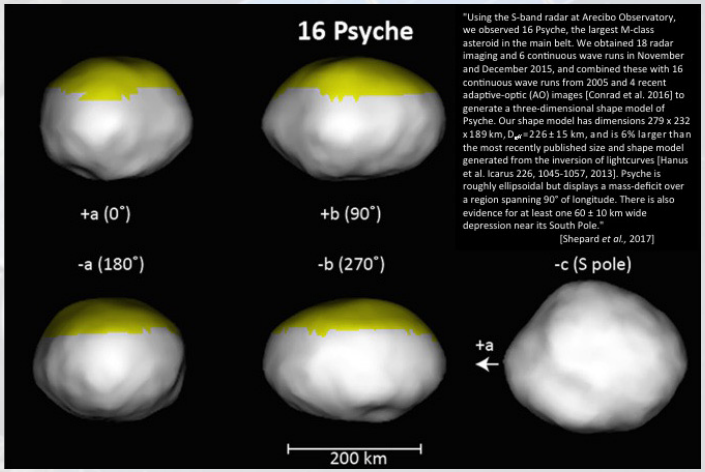
Why Psyche ?

- Psyche was the 16th asteroid discovered
  - Roughly elliptical, 279 x 232 x 189 km ±10% (Shepard et al., 2017)
  - Discovered by Annibale de Gasparis of Naples on March 17, 1852
  - a = 2.921 AU, P_{orb} = 4.99 yr, P_{rot} = 4.196 hrs

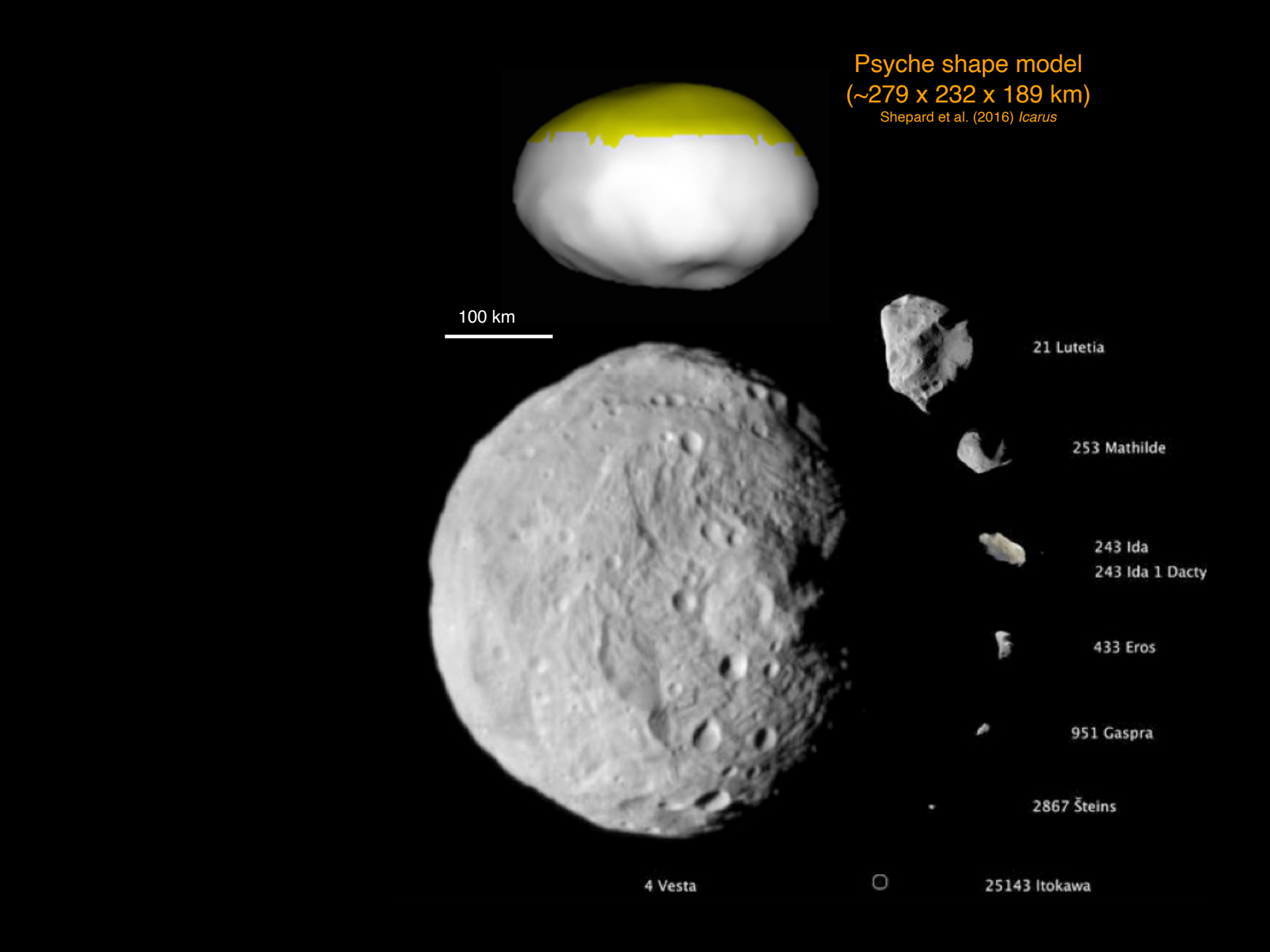


Shape model derived from Earth-based radar

- What is Psyche composed of ?
  - Psyche is a M type asteroid
  - Source of some iron meteorites?
  - Thought to metallic planetary core
  - Density = 4.17 g/cc (Farinocchia et al., 2024)
  - Solid body, ~40% porosity => Regolith
  - Primitive body, metals & 10% silicates, some spectral evidence for minor H_2O ice on surface

Iron meteorite

- Psyche was imaged by telescopes
- How big is (16) Psyche?


Psyche shape model
(~279 x 232 x 189 km)
Shepard et al. (2016) *Icarus*
100 km
21 Lutetia
253 Mathilde
243 Ida
243 Ida 1 Dacty
433 Eros
951 Gaspra
2867 Šteins
4 Vesta
25143 Itokawa

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Asteroid: Peter Rubin/Caltech-JPL
Spacecraft: SSL

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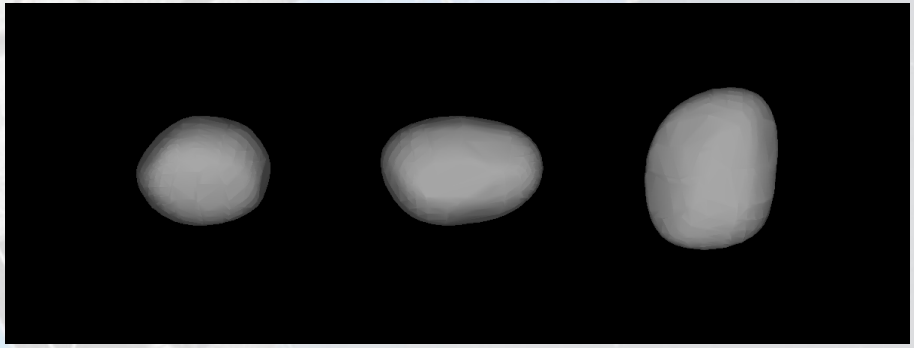
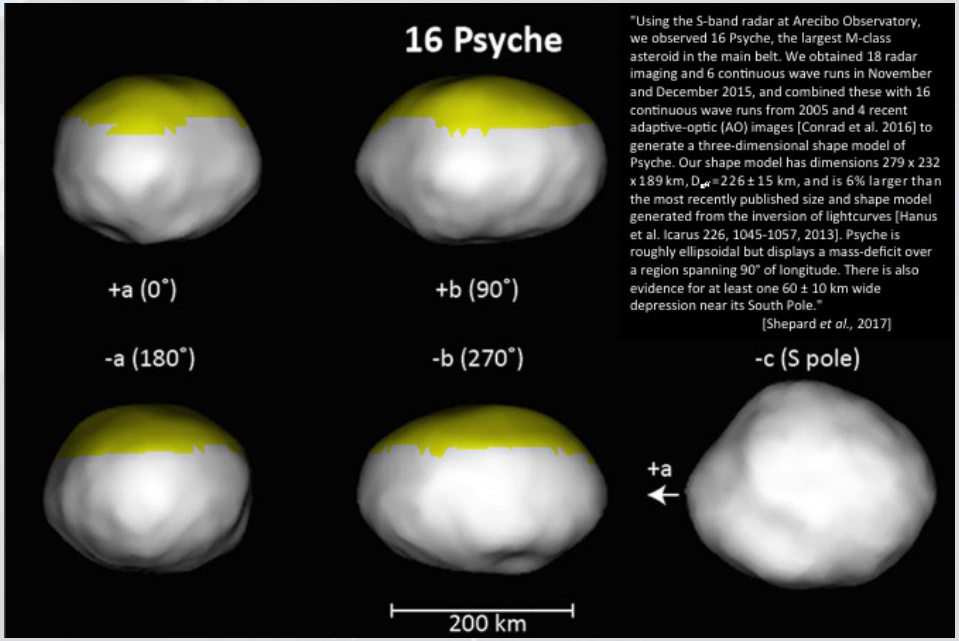
NASA *Psyche* Mission

- Driving question: Is 16 Psyche the core of an asteroid parent body?
- Five definitive science objectives:
  - ✧ Is Psyche a core, or did it never undergo melting?
  - ✧ What are the relative ages of its surface regions?
  - ✧ Do small metal bodies incorporate the light elements expected to be inside Earth's high-pressure core?
  - ✧ Did Psyche form under more oxidizing or more reducing conditions than Earth's core?
  - ✧ What is the unique topography of this metal world?

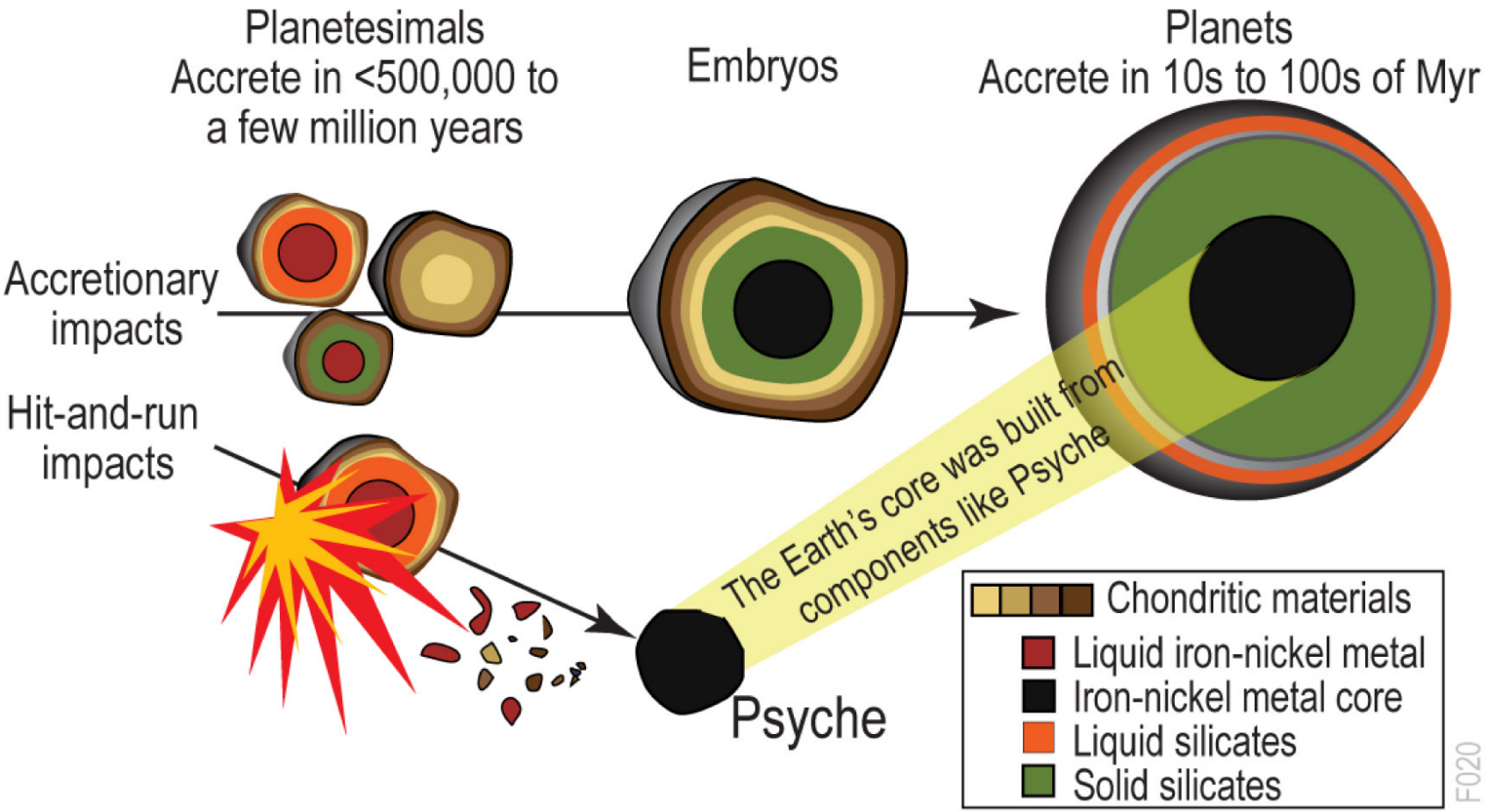
3D model derived from light curves

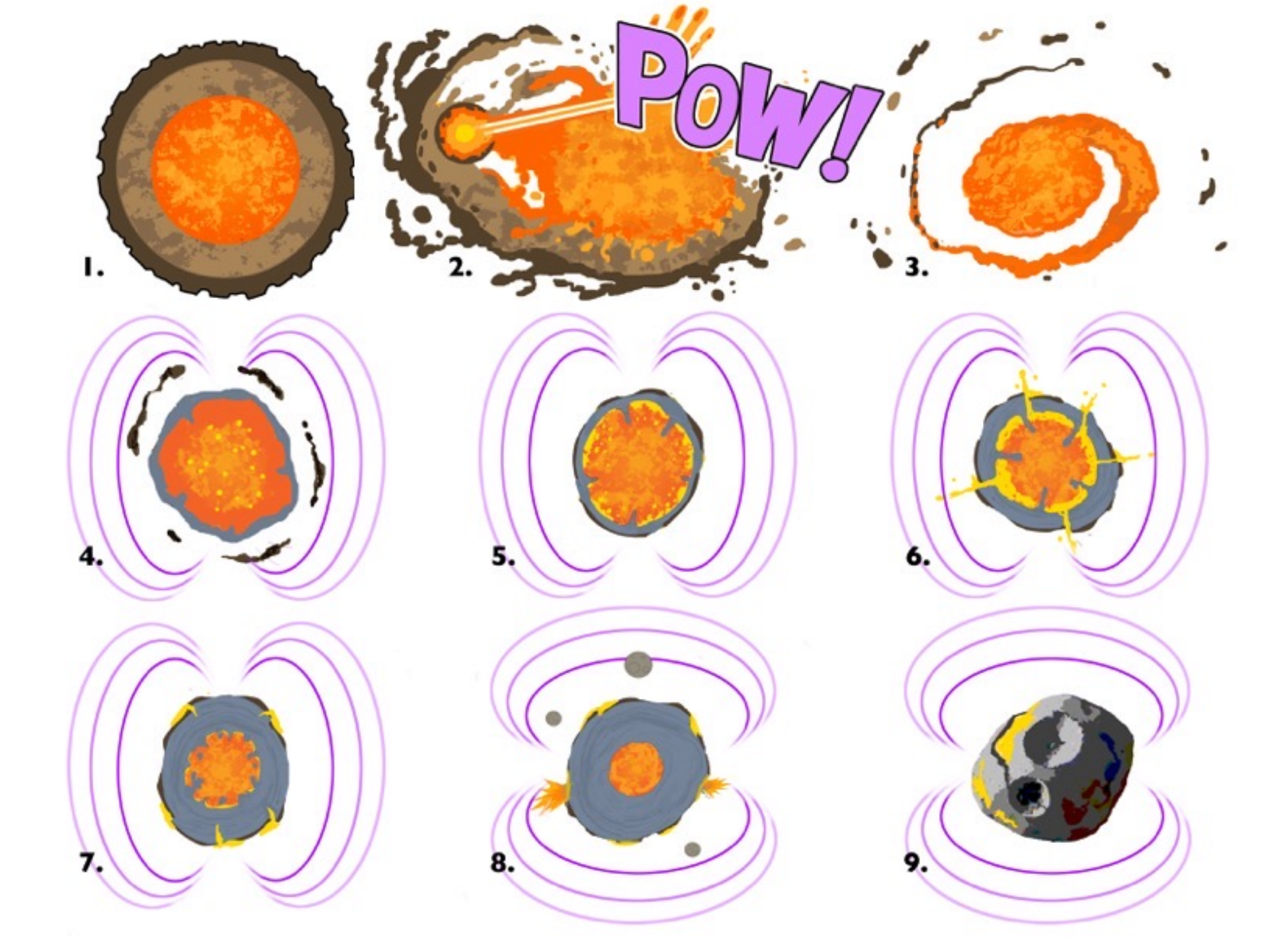


Shape model derived from Earth-based radar

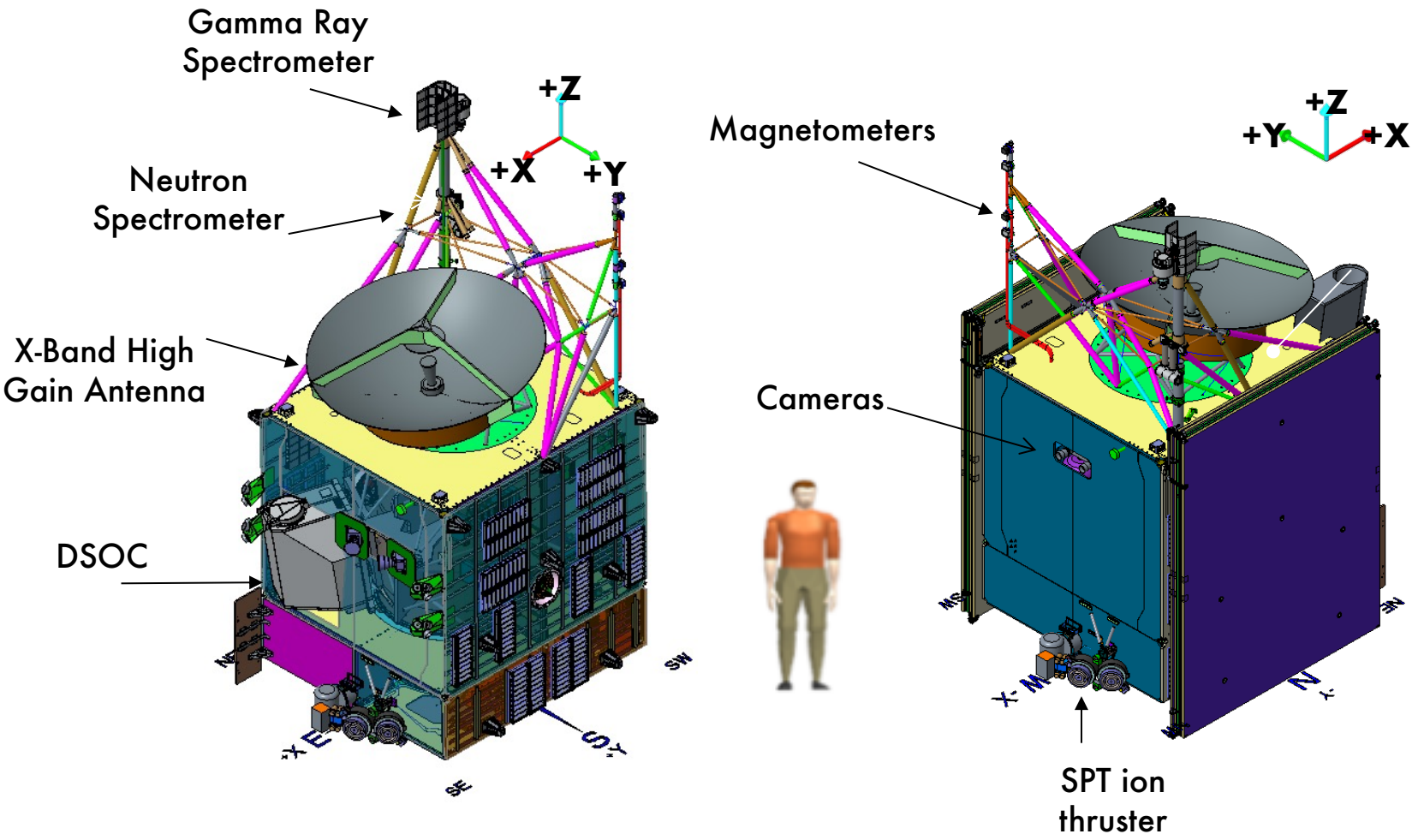


What is 16 Psyche?

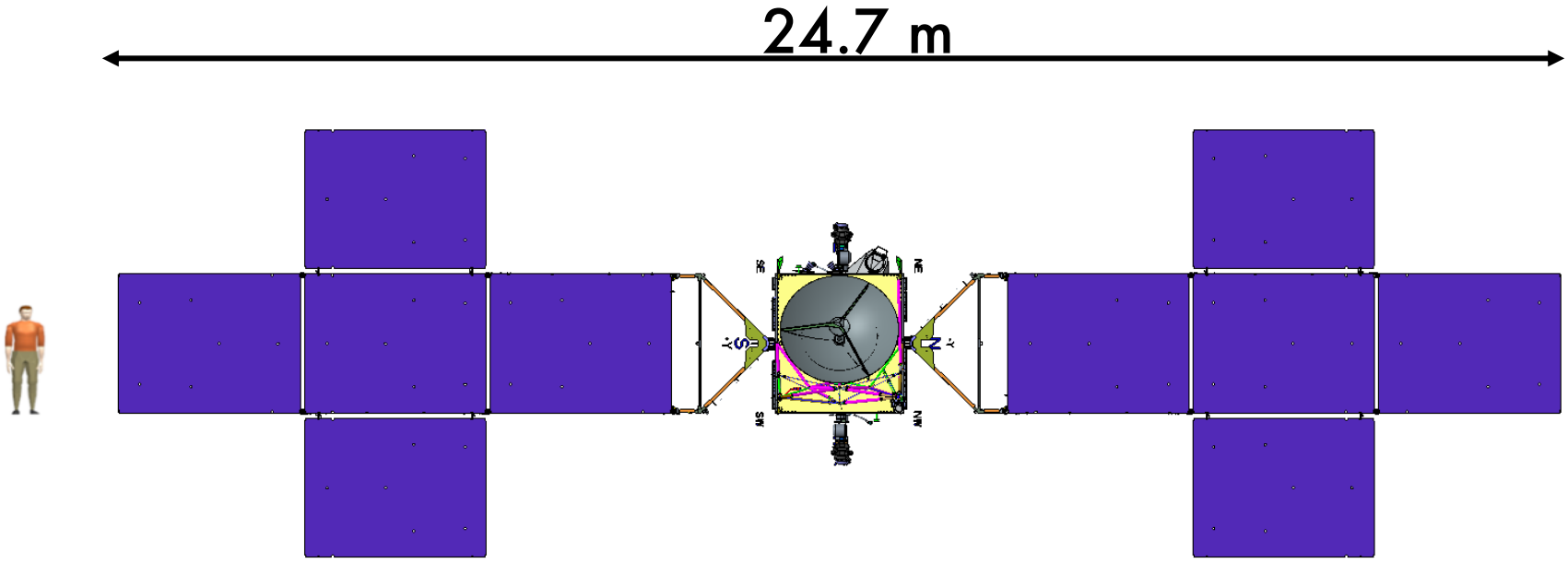



POW!
1.
2.
3.
4.
5.
6.
7.
8.
9.

Psyche Spacecraft



Psyche Spacecraft



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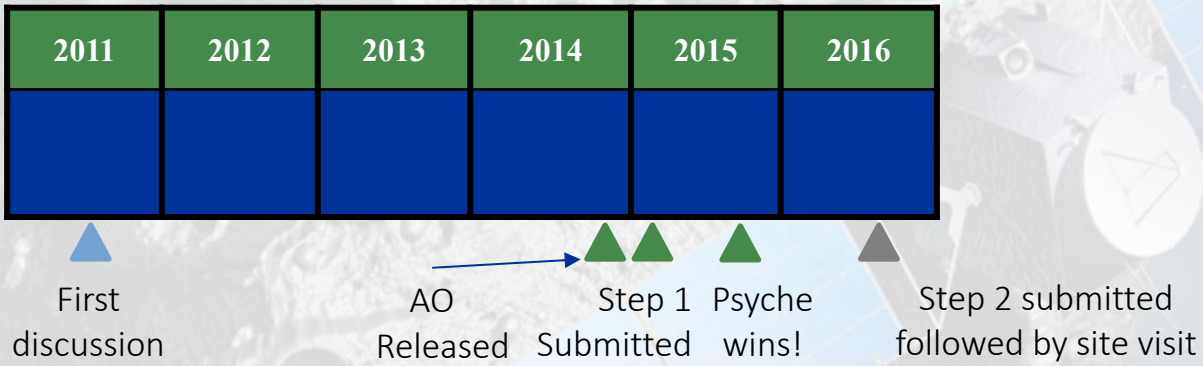
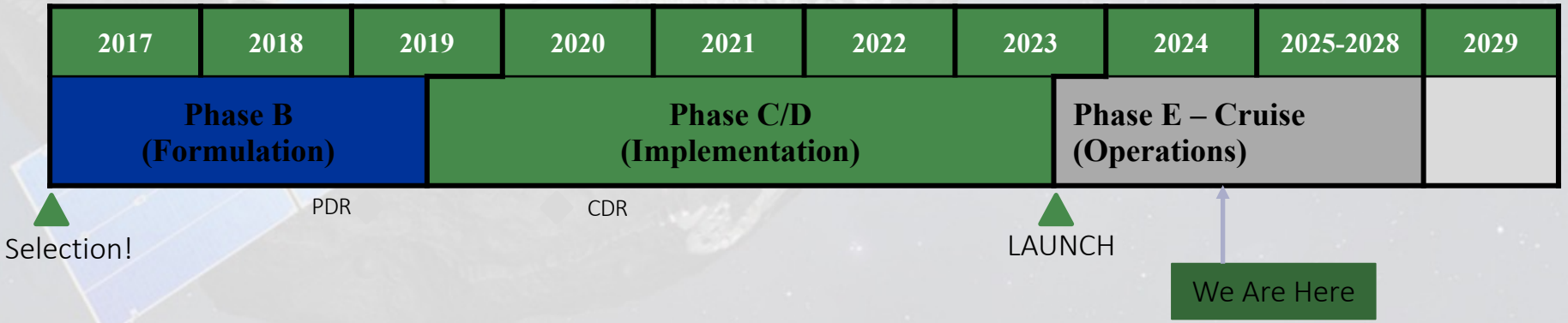
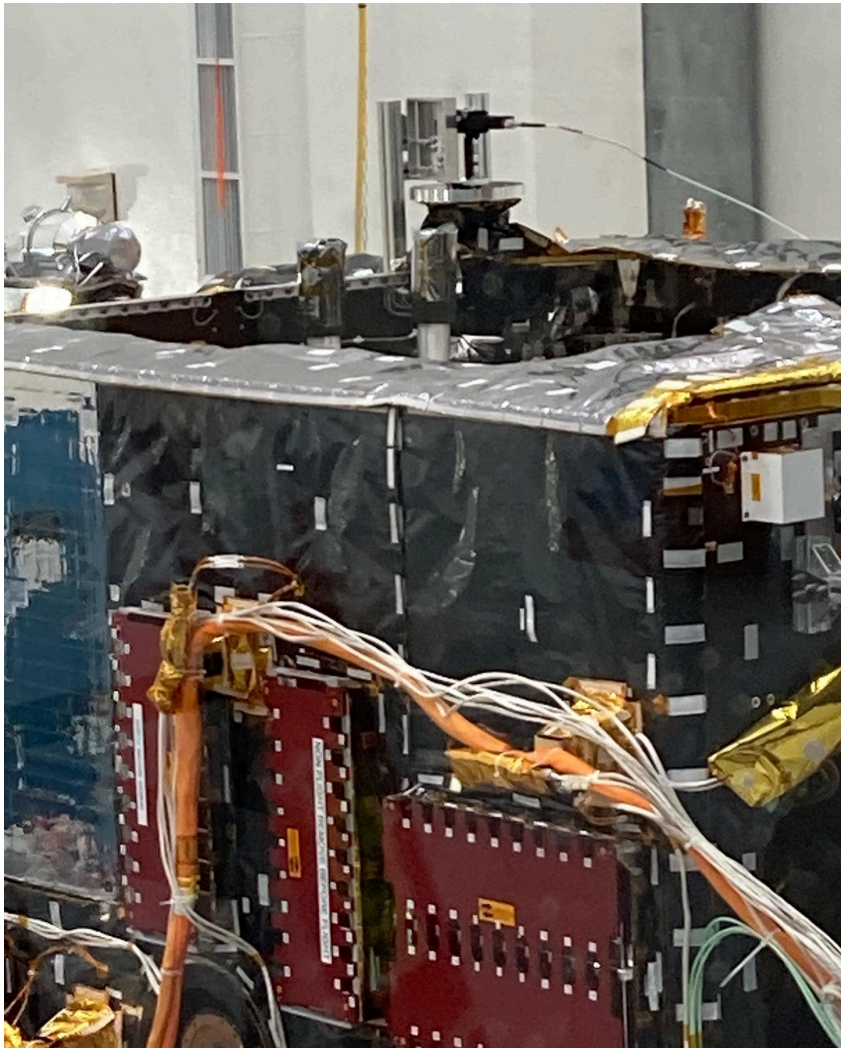
Psyche Mission Project Development





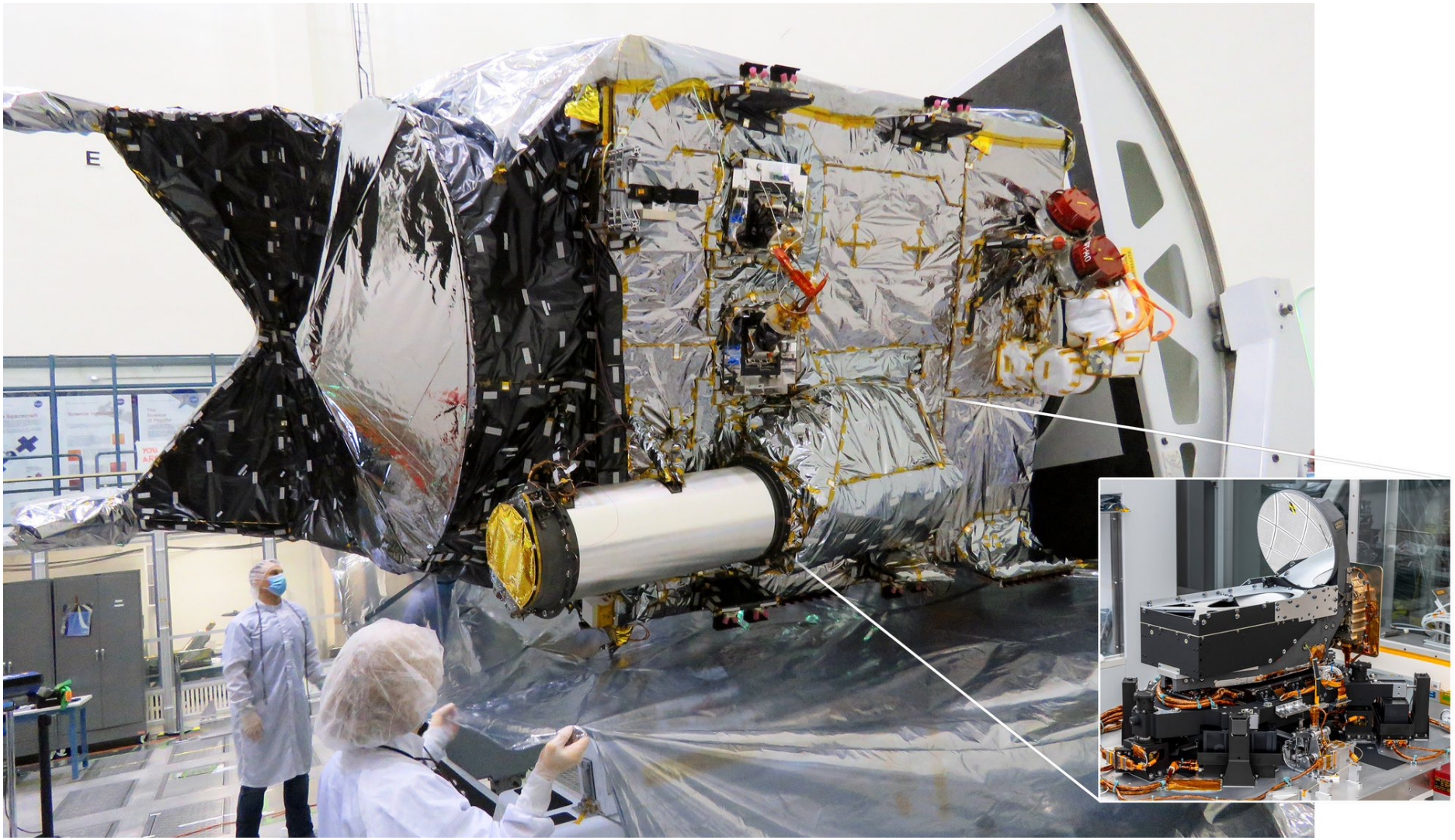
Asteroid: Peter Rubin/Caltech-JPL
Spacecraft: SSL

Construction Completed 2022



Shipped to KSC April 30, 2022!!

1-Year Launch Delay: 2022-2023



Wednesday, October 11, 2023

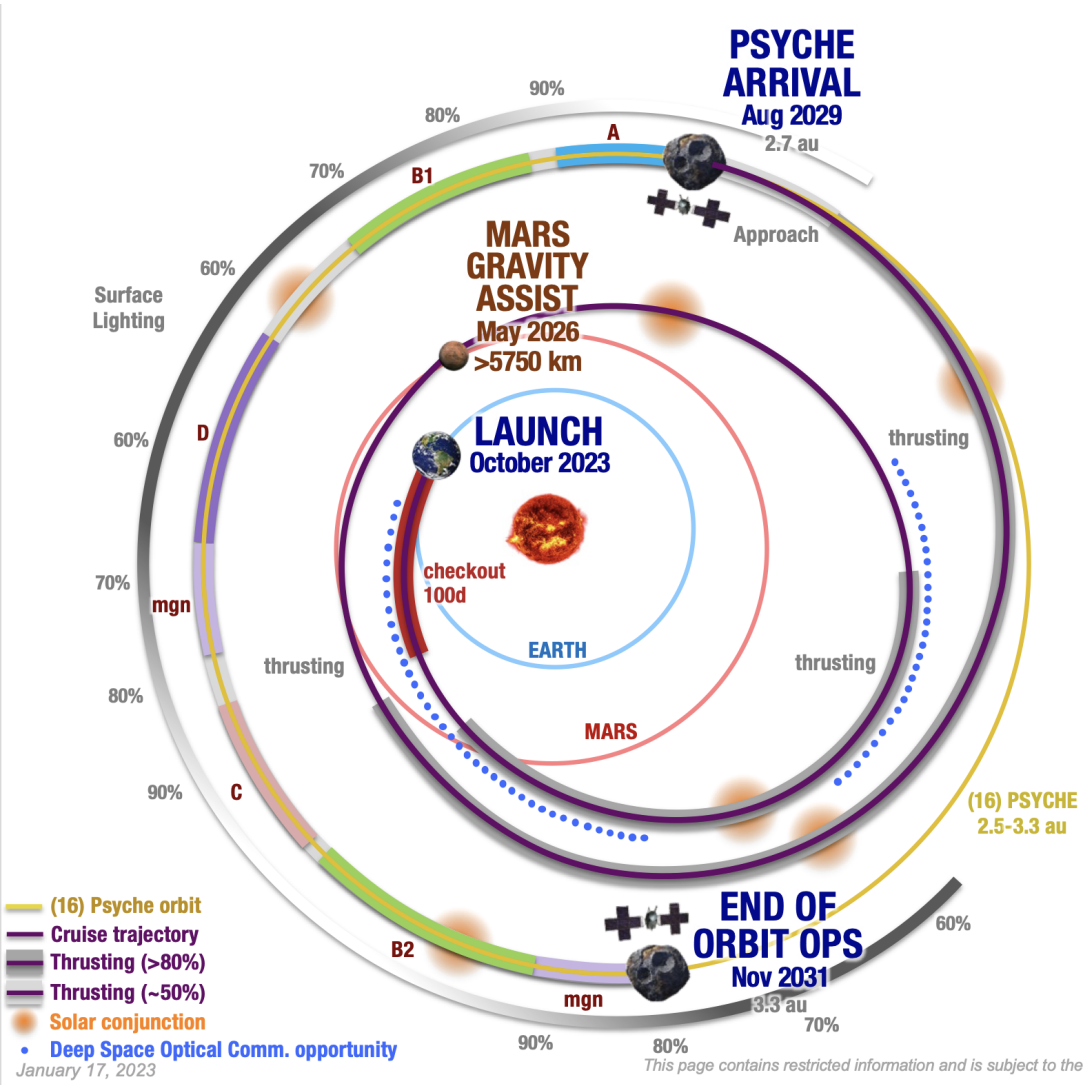
Wednesday, October 11, 2023

Friday, October 13th

Instrument Calibration during Cruise

- Colorized image made from IMGA, mosaic position 9
  - Filter 1, 6 sec as Luminance
  - Filter 3 (493 nm) in Blue
    - Sensitive to Oxygen III
  - Filter 4 (548 nm) in Green
    - Sensitive to Hydrogen Beta
  - Filter 5 (723 nm) in Red
    - Sensitive to Sulfur II
- Images were dark subtracted, median filtered, and contrast adjusted

Psyche's Trajectory



Mission Phases

Phase	Dates
Launch*	Oct 2023
Initial Checkout	Oct 2023 – Jan 2024 (100 days)
Cruise	Jan 2024 – May 2029 (64 months)
Cruise 1	Jan 2024 – Mar 2026 (26 months)
Mars Gravity Assist	Mar – May 2026 (62 days)
Cruise 2	May 2026 – May 2029 (36 months)
Approach	May – Aug 2029 (100 days)
Orbital Ops	Aug 2029 – Nov 2031 (26 months)
*Launch is the only critical event	

Courtesy NASA/JPL-Caltech

Psyche Orbital Operations

Orbital operations

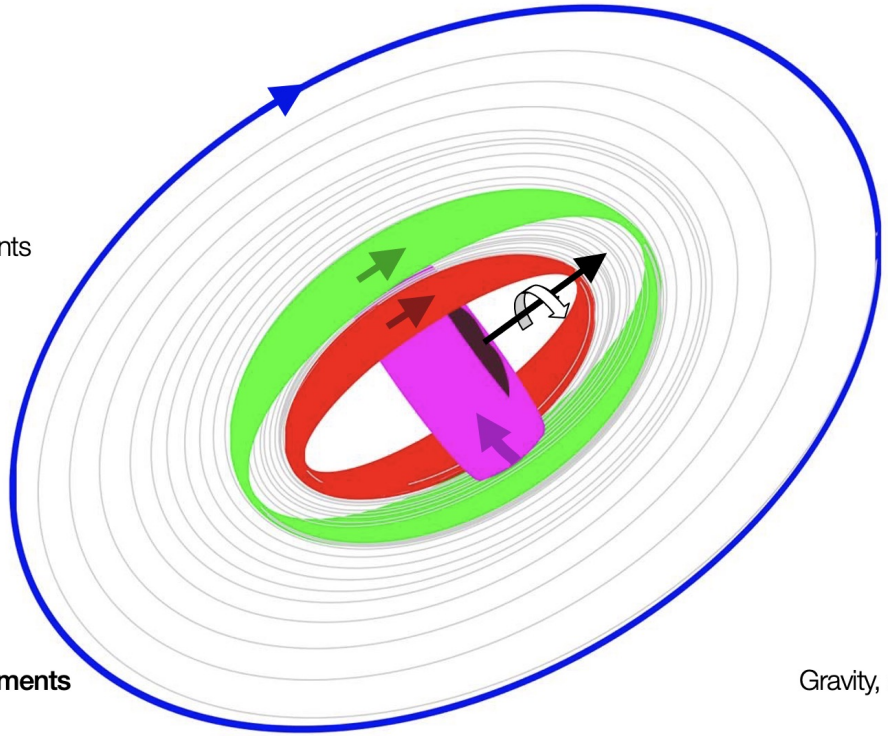
Sun location (into the page) during Orbit A; Sun rotates counter-clockwise over time; by Orbit B2, Sun is towards the bottom (and out of the page)

ORBIT A

709 km alt, 90° inclination
32.6 hour orbit period
56 days = 41 orbits
Imaging and mapping
Magnetic field and gravity measurements

ORBIT B (B1, B2)

303 km alt, 90° inclination
11.6 hour orbit period
B1: 92 days = 190 orbits
B2: 100 days = 206 orbits
Topography, geologic mapping
Magnetic field and gravity measurements



ORBIT C

190 km alt, 90° inclination
7.2 hour orbit period
100 days = 333 orbits
Topography measurements
Magnetic field and gravity measurements

ORBIT D

75 km alt, 160° inc
3.6 hour orbit period
100 days = 666 orbits
Composition measurements
Gravity, mapping, and magnetic field measurements

All orbit altitudes based on the Shepard 2021 model
Transitions between orbits A to B1 and C to B2 are shown in gray; transfers to/from D are not shown due to their complexity
No eclipses are expected in orbits or transfers

Operations: *Psyche* Orbits

Approach: (100 days)
- Optical navigation and instrument calibration
- Hazard assessment (satellite search)
- Psyche spin axis and rotation period measurements

Orbit A: Characterization: 56 days (41 orbits)
- Magnetic field detection
- Nadir mapping for preliminary shape, global color mapping, and gravity field characterization

Image resolution 35 m/px

Orbit B: Topography: 76 days (162 orbits)
- Two Nadir and seven off-nadir imaging cycles for topography (followed by solar conjunction)
- Global color maps, gravity science
- Magnetic field characterization

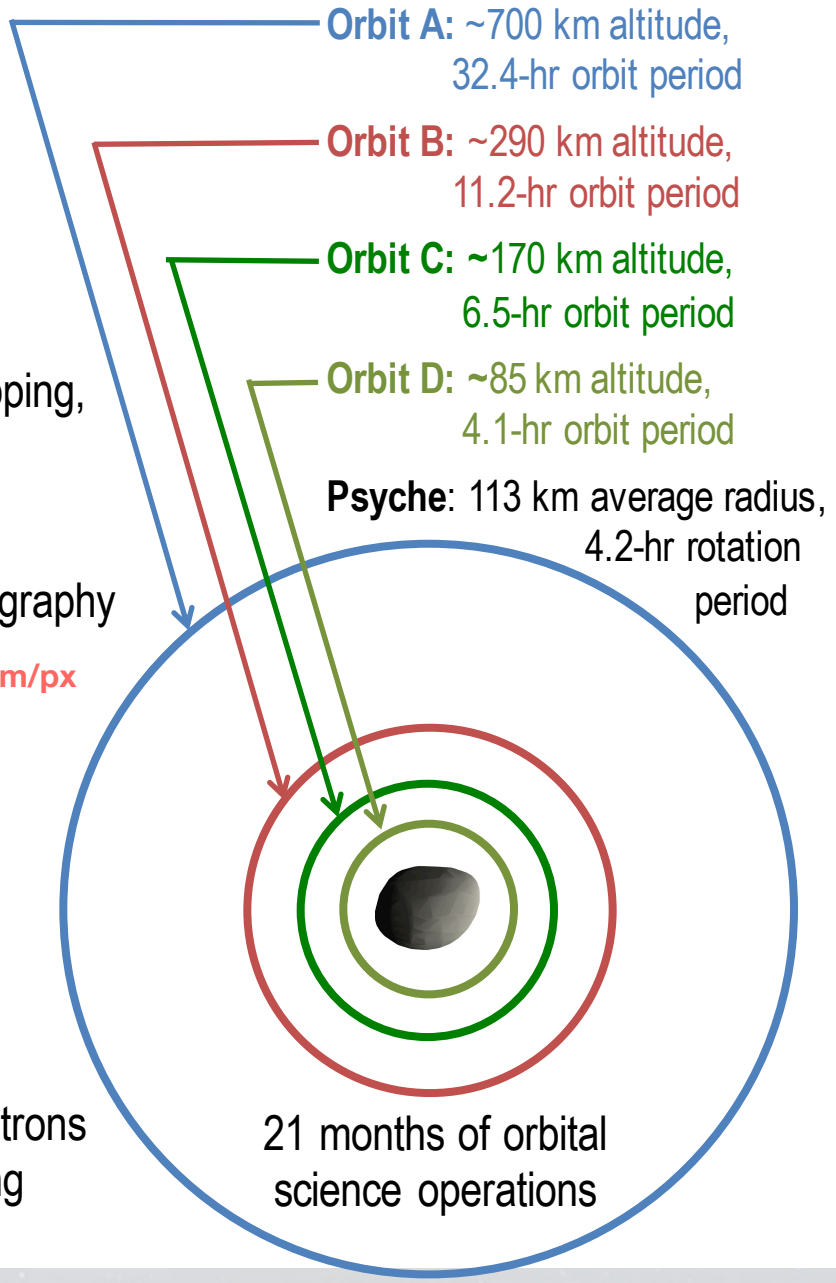
Image resolution 15 m/px

Orbit C: Gravity Science: 100 days (369 orbits)
- Gravity field mapping
- Continue magnetic field mapping and crater statistics

Image resolution 9 m/px

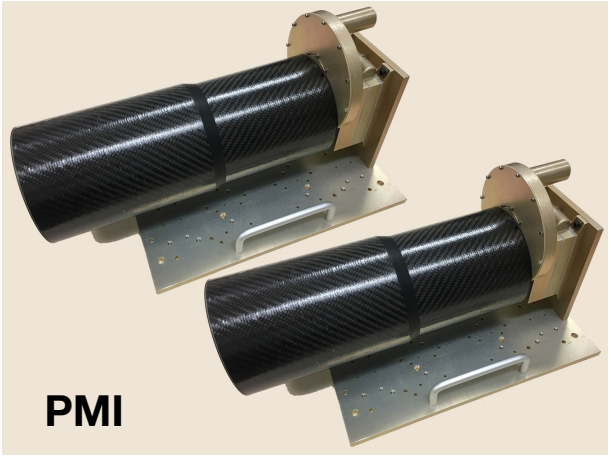
Orbit D: Elemental Mapping: 100 days (585 orbits)
- Map elemental composition with gamma rays and neutrons
- Continued imaging, gravity, and magnetic field mapping

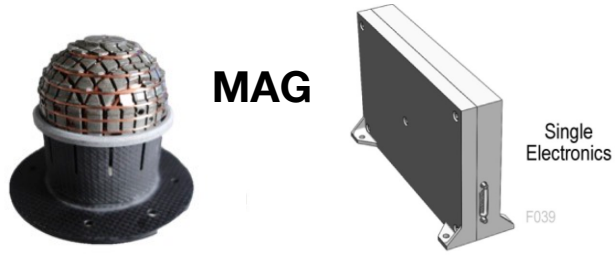
Image resolution 4 m/px

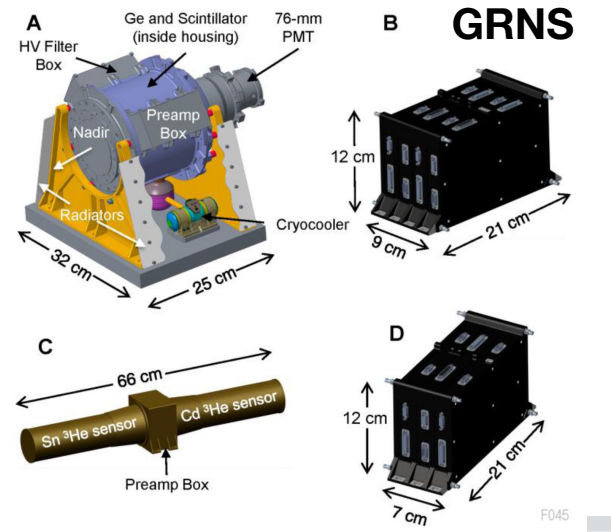


Psyche Instruments

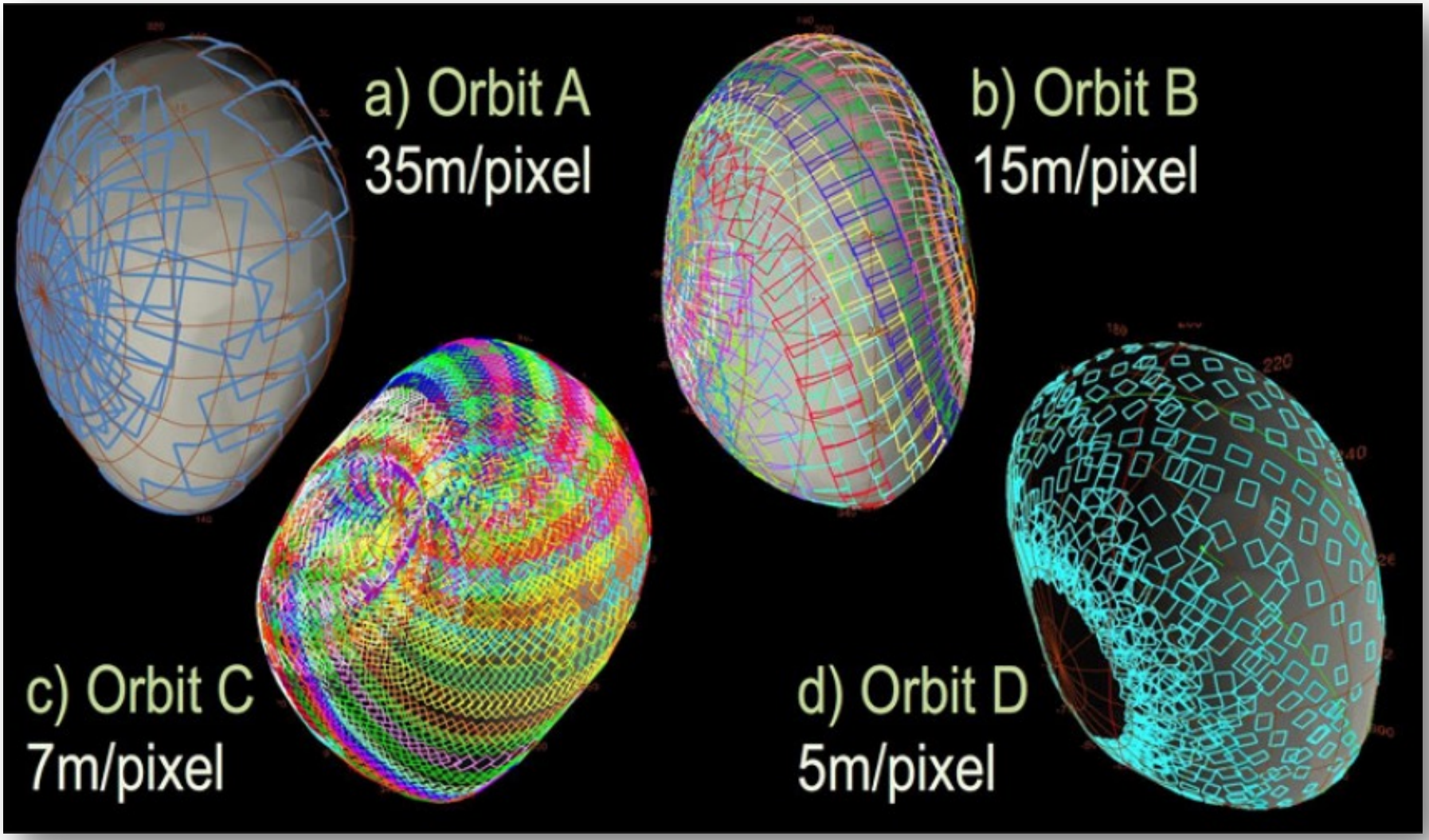
- Three remote sensing instruments
  - ✧ Multispectral Imager (2 for redundancy)
  - ✧ Paired Magnetometers
  - ✧ Gamma-Ray & Neutron Spectrometer (GRNS)
- Imager: ASU, Malin SSS
  - ✧ Images surface for morphology, albedo, color
  - ✧ Clear filter + 7 color filters
  - ✧ Determines topography via stereo imaging & production of digital terrain models (DEMs)
- Magnetometer: MIT, Danish Tech. Univ.
  - ✧ Measures magnetic fields to sensitivity of 0.1 nT
  - ✧ Dual fluxgate magnetometers on 2-meter boom
- GRNS: APL
  - ✧ Measures elemental abundances of surfaces, especially Fe, Ni, Si, and K
  - ✧ Helps derive compositions of surface
- Gravity Science Experiment: JPL
  - ✧ Assess gravity of body via variation of X-band radio signals; derives gravitational field







Psyche Imaging



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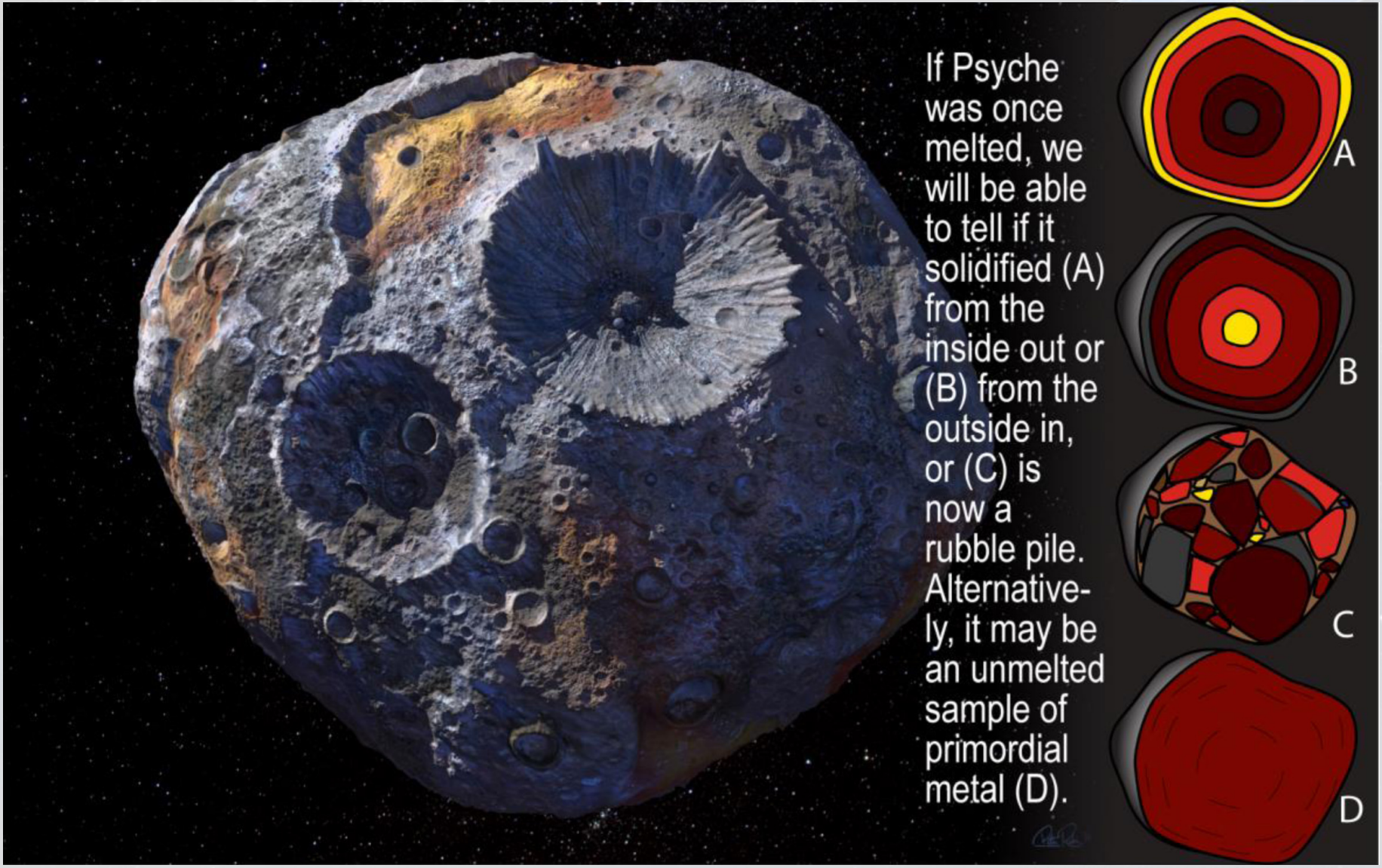
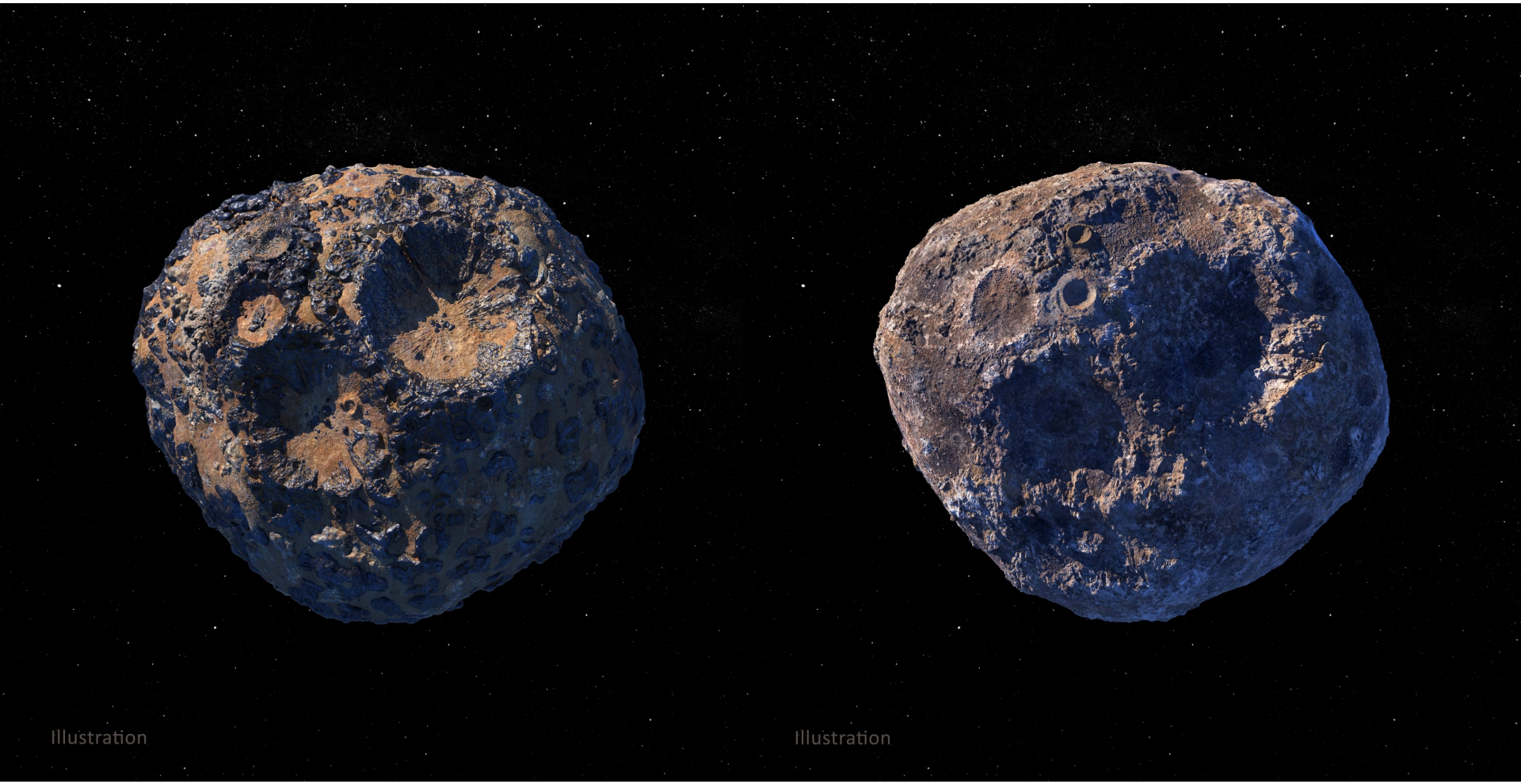
What is 16 Psyche?



Asteroid: Peter Rubin/Caltech-JPL
Spacecraft: SSL

What Have We Learned About 16 Psyche?



Illustration

Illustration

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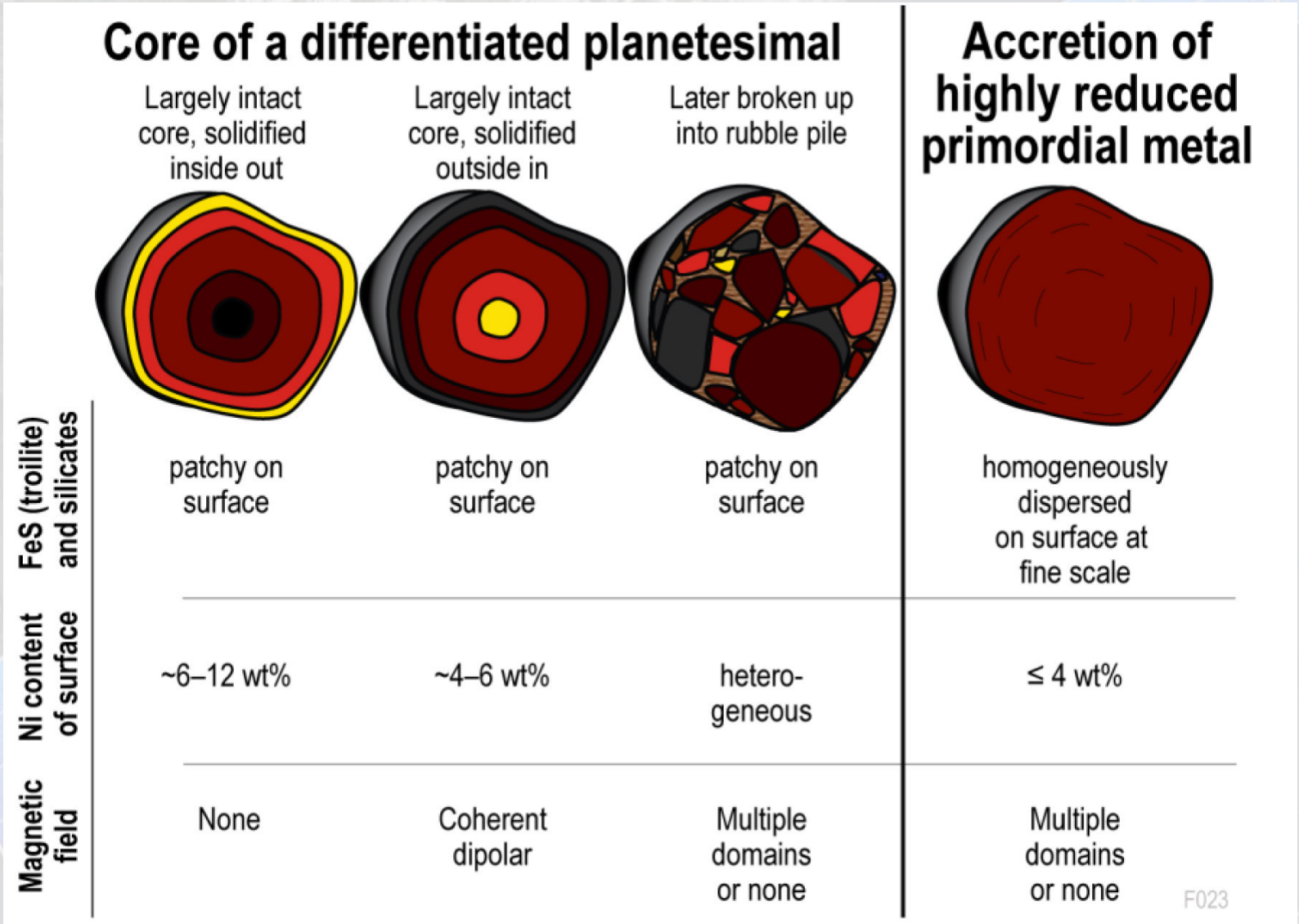
What is 16 Psyche?



Spacecraft: SSL

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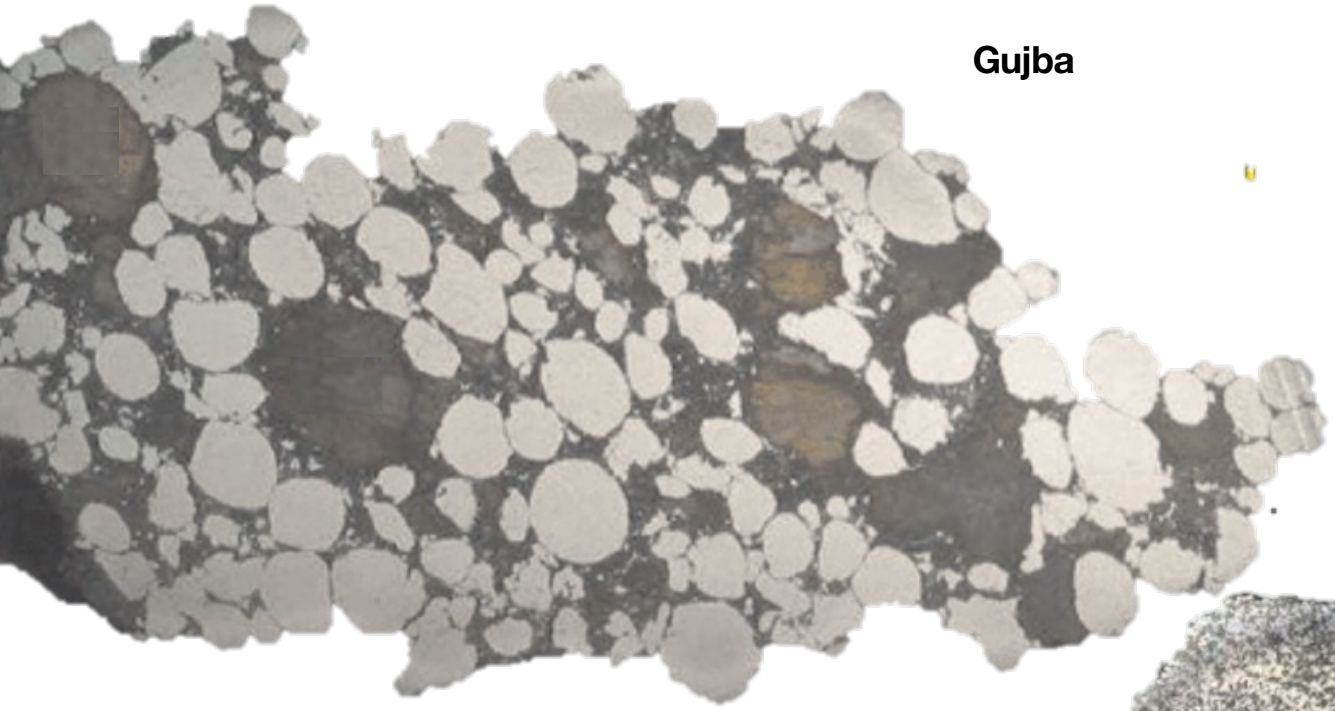
What is 16 Psyche?

No one has seen an impact crater in metal!

Meteorites that match Psyche's spectra: The CB Chondrites



Gujba

Krot et al., 2005

Isheyevo

http://www.meteoritestudies.com

Dibb et al. (2023)

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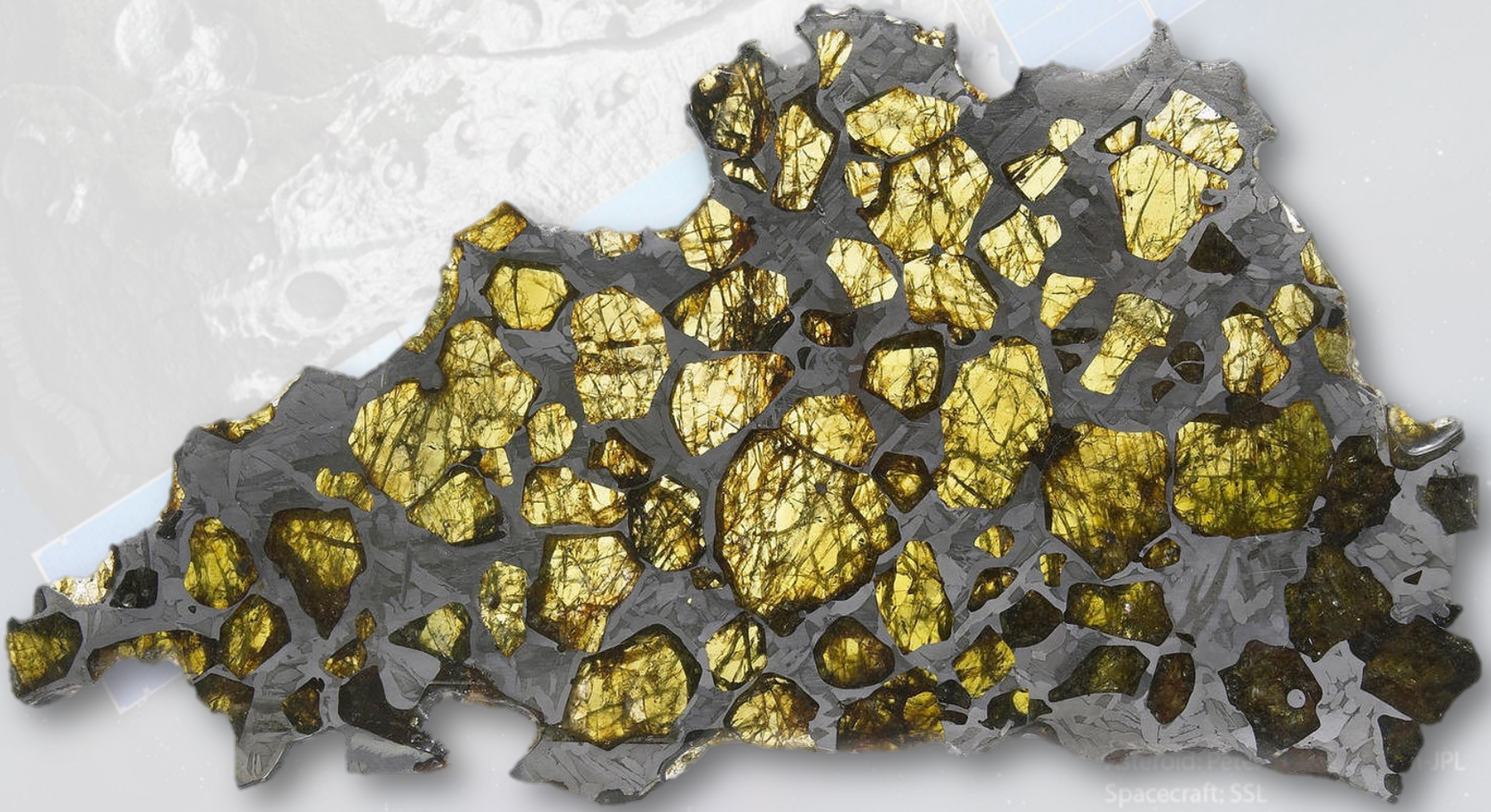
What is 16 Psyche?

Could parts of the surface could be made of pallasite?



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Summary

- Asteroids are the rocky remnants from the formation of the Solar System
- On January 4, 2017, NASA selected Arizona State University to lead a *Discovery*-class mission to M-class asteroid 16 Psyche
- NASA's *Psyche* spacecraft, just like *Dawn*, uses solar electric propulsion to move through the Solar System
- *Psyche* carries three instruments: a visible imager, a magnetometer, and a gamma-ray and neutron spectrometer
- Psyche spacecraft launched Oct. 13,2023!
- ICO completed Jan. 26, 2024! **We are Cruising to Psyche!**
  Mars Flyby: May 2026
  Arrival at (16) Psyche: Aug. 2029
- Stay tuned!

Rotation of Psyche at 20N

Shepard et al. 2021 PSJ