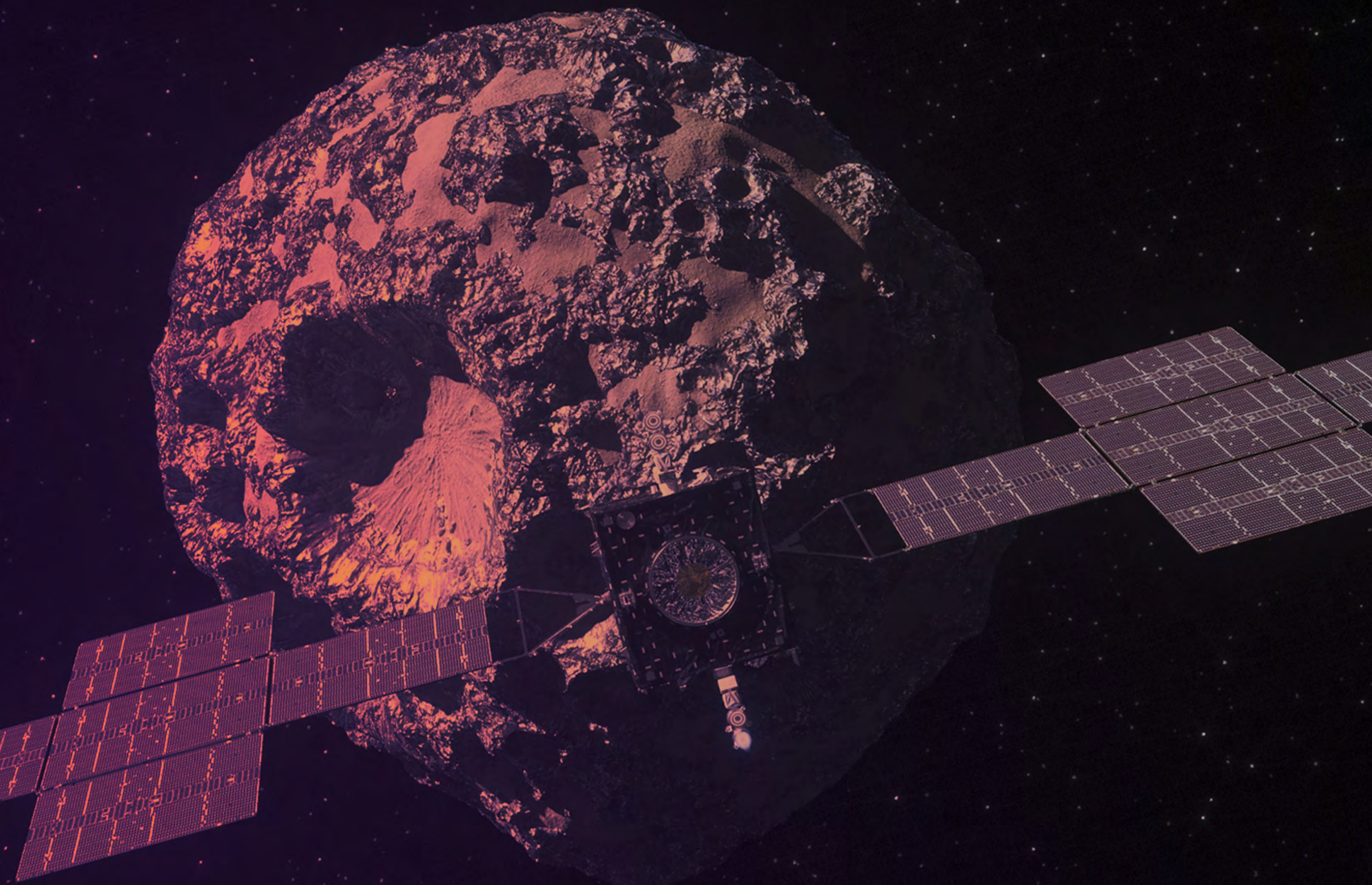
National Aeronautics and Space Administration

PSYCHE

Press Kit / September 2023



www.nasa.gov

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Introduction

PSYCHE Press Kit

NASA's Psyche mission is the first to a metal-rich asteroid, which is also named Psyche. The agency is targeting a launch period that opens Oct. 5, 2023. The mission will ride to space on a SpaceX Falcon Heavy rocket from NASA's Kennedy Space Center in Florida.

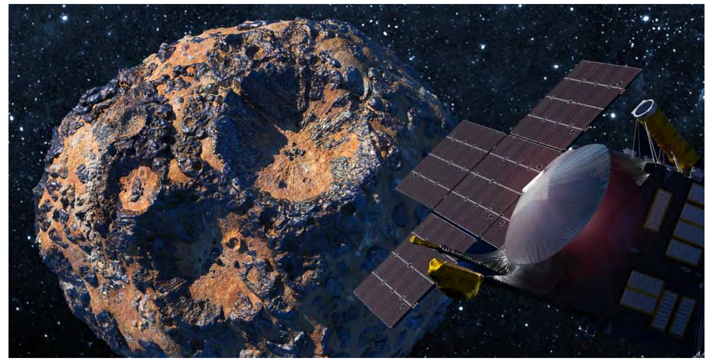
Cruising through space with a super-efficient solar electric propulsion system, the Psyche spacecraft is expected to arrive at the asteroid to begin science operations in 2029. It will orbit this unique world for at least 26 months.

Attached to Psyche is the Deep Space Optical Communications technology demonstration, a NASA experiment that will test optical, or laser, communications beyond the Moon.

6 Things to Know About the Psyche Mission

Since the asteroid Psyche was discovered in 1852, scientists have only been able to study this potato-shaped object from afar. Over the years, they have discerned that Psyche is an unusual object likely rich in metal, but many questions about its origin and composition remain. The Psyche mission will be the first to study this kind of planetary object up close. Here are six key facts about the mission:

1. NASA wants to learn more about the origins of our solar system. Investigating the asteroid Psyche is important because the asteroid could be part of a building block of an early rocky planet.



Judging from data obtained by Earth-based radar and optical telescopes, scientists hypothesize that the asteroid Psyche could be part of the metal-rich interior of a planetesimal, a building block of a rocky planet. (The rocky planets are Mercury, Venus, Mars, and our home planet, Earth.) It could be that Psyche collided with other large bodies during its early formation and lost its outer rocky shell.

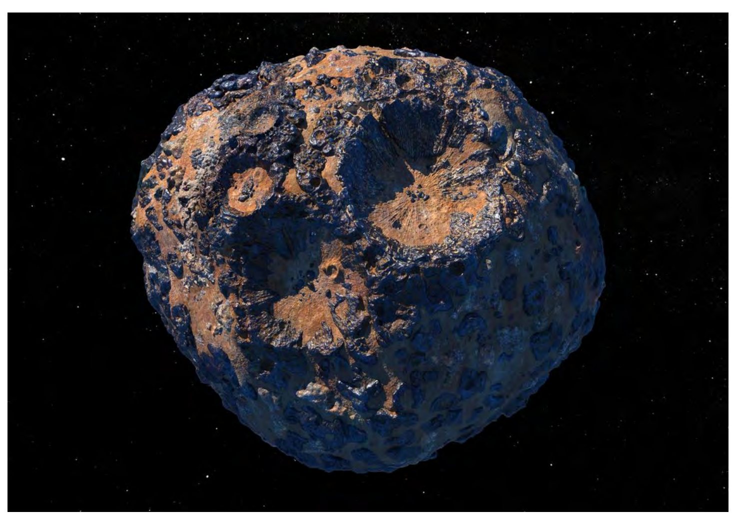
NASA's Psyche Mission to an Asteroid: Official NASA Trailer
bit.ly/47F6StC

Humans can't bore a path to Earth's metal core – or the cores of the other rocky planets – so visiting Psyche could provide a one-of-a-kind window into the history of violent collisions and accumulation of matter that created planets like our own.

SWOT's eye in the sky will provide a truly global view of Earth's surface water, enriching humankind's understanding of how the ocean reacts to and influences climate change along with what potential hazards – including floods – lay ahead in different regions of the world.

2. Psyche is so unusual, it could also surprise scientists and suggest a different story of how solar system objects formed.

While rocks on Mars, Venus, and Earth are flush with iron oxides, Psyche's surface – at least when studied from afar – doesn't seem to feature much of these chemical compounds. This suggests that Psyche's history differs from standard stories of planetary formation.



Scientists are excited to visit Psyche up close for the first time so they can learn more about its origin. If the asteroid is leftover core material from a planetary building block, they look forward to learning how its history resembles and diverges from that of the rocky planets. And if scientists discover that Psyche is not an exposed core of an early planetary building block, it may prove to be an even rarer kind of primordial solar system object, one that's never been seen before. One of the most exciting aspects of this mission is the possibility of the unexpected.

3. Three science instruments and a gravity science investigation on the spacecraft will help sort out these solar system origin stories.

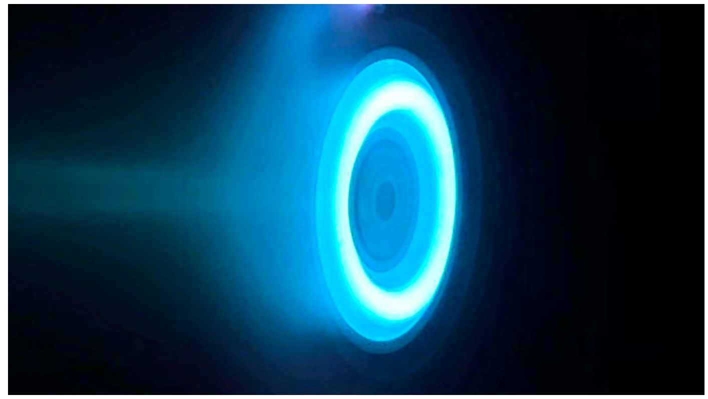
Psyche's magnetometer will look for evidence of an ancient magnetic field at the asteroid Psyche. A residual magnetic field would be strong evidence the asteroid formed from the core of a planetary body.

The orbiter's gamma-ray and neutron spectrometer will help scientists determine the chemical elements that make up the asteroid. Figuring out what Psyche is composed of will enable scientists to better understand how it formed.

The spacecraft's multispectral imager will provide information about the mineral composition of Psyche as well as its topography.

The Psyche science team will harness the telecommunications system, used to send commands to and receive data from the spacecraft, to conduct gravity science also. By analyzing the radio waves the spacecraft communicates with, scientists can measure how the asteroid Psyche affects the spacecraft's orbit. From that information, scientists can determine the asteroid's rotation, mass, and gravity field, gaining additional insights into the composition and structure of the asteroid's interior.

4. The Psyche spacecraft will use a special kind of super-efficient propulsion system for the first time beyond the Moon.



Powered by Hall-effect thrusters, Psyche's solar electric propulsion system harnesses energy from large solar arrays to create electric and magnetic fields. These, in turn, accelerate and expel charged atoms, or ions, of a propellant called xenon (a neutral gas used in car headlights and plasma TVs) at such high speed, it creates thrust. The plasma, or ionized gas, will emit a sci-fi-like blue glow as it trails behind Psyche in space. Each of Psyche's four thrusters, which will operate only one at a time, exert at most the same amount of force that one AA battery would exert on the palm of your hand. Over time, in the frictionless void of space, the spacecraft will slowly and continuously accelerate.

Psyche's propulsion system builds on similar technologies used by NASA's Dawn mission, but it will be the agency's first mission to use Hall-effect thrusters in deep space. To date, Hall thrusters have been used only by an ESA (European Space Agency) mission to the Moon.

5. Psyche is a collaboration.

The Psyche mission is only possible by drawing together resources and know-how from NASA, universities, and industry.

The mission's leader – Principal Investigator Lindy Elkins-Tanton – is based at Arizona State University (ASU) in Tempe. The partnership with ASU enables collaboration with students nationwide. This offers greater opportunities to train future instrument and mission leads in science and engineering, and to inspire additional student projects involving art, entrepreneurship, and innovation. Over a dozen other universities and research institutions are represented on the mission team.

NASA's Jet Propulsion Laboratory in Southern California, a leader in robotic exploration of the solar system, manages the mission for the agency's Science Mission Directorate in Washington. Managed for NASA by Caltech in Pasadena, JPL is also responsible for system engineering, integration and test, and mission operations.

NASA's Launch Services Program at Kennedy Space Center manages launch operations and procured the SpaceX Falcon Heavy rocket.

Maxar Technologies is a key commercial participant in the mission. Its team in Palo Alto, California, delivered the solar electric propulsion chassis – the main body of the spacecraft – and most of its engineering hardware systems.

6. The Psyche mission wants you to be part of the journey, too.

NASA and the Psyche mission team believe space exploration is for everyone. The general public, students of all ages, and teachers can find an abundant list of activities and opportunities on the mission's "get involved" webpage.

Opportunities include Psyche-focused undergraduate projects for senior capstone courses and an annual internship to interpret the mission through artistic and other creative works. Students and teachers can also find age-appropriate lessons, craft projects, and videos on the page. A virtual launch experience is planned as well, with more information at nasa.gov/specials/virtualguest/.

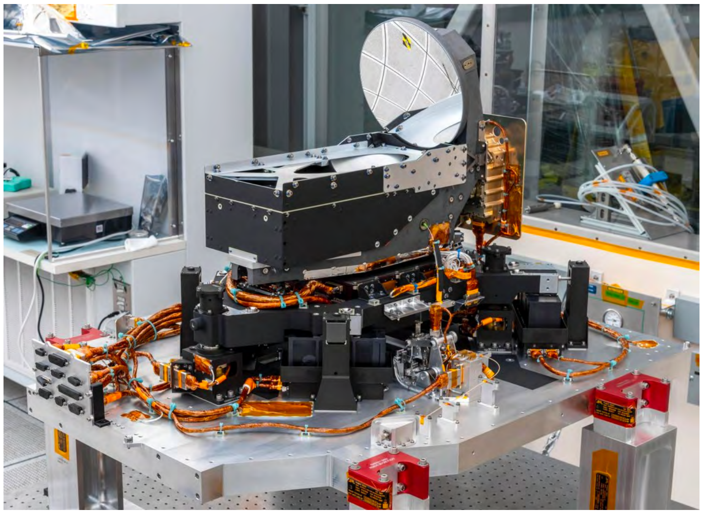
Image credit: NASA/M.H. Lewis

The mission websites nasa.gov/psyche and psyche.asu.edu will post official news about the spacecraft's journey, along with glimpses of team members' workdays. NASA and ASU will also post regular social media updates on Facebook, Instagram, and X.

NASA's Eyes on the Solar System, a free web-based visualization tool, will track the location of the spacecraft in real time 3D. Visit go.nasa.gov/45k0OVY to see where Psyche is in the solar system.

About two months after launch, as the team performs an initial checkout of the spacecraft and science instruments, the mission expects to get the first images back from its multispectral imager. Once the team confirms the imager is functioning as expected, a webpage will feature the unprocessed, or raw, images flowing straight from the spacecraft to Earth. The first images will just be fields of stars, but you'll be able to follow the spacecraft's journey with Psyche's own "eyes" as it heads toward its asteroid target and orbits this intriguing metal-rich world.

What's Riding Along With Psyche?



Deep Space Optical Communication
Attached to a side of the Psyche spacecraft is a pioneering technology demonstration: NASA's Deep Space Optical Communications (DSOC) experiment. Using a near-infrared laser, DSOC will be the agency's first test of high-bandwidth optical communications between Earth and distances far exceeding the Moon.

To meet the demands of future space missions, current state-of-the-art radio systems would require huge increases in hardware size, mass, and power to transmit and receive high-bandwidth data such as high-definition images and video. Optical communications – also called laser communications – could potentially provide this essential bandwidth enhancement without requiring such hardware increases. Much like upgrading old telecommunications infrastructure on Earth with fiber optics to meet growing data demands, going from radio communications to laser communications would increase current data rate capacity by 10 to 100 times.

DSOC is not intended to relay Psyche mission data since the technology demonstration is planned for the first two years of the spacecraft's cruise. But if it proves successful, the technology will be used by future human and robotic spacecraft to transmit huge volumes of science data, allowing more innovative space mission concepts to take flight. Ultimately, DSOC may pave the way for broadband communications that will help support humanity's next giant leap: when NASA sends astronauts to Mars.

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Products and Events

News Releases, Features, Advisories, and Status Reports

Progress reports on Psyche and DSOC's road to launch, including the latest updates on launch dates, can be found on the NASA launch blog.

News, updates, and feature stories about the Psyche mission will be available at nasa.gov/psyche and psyche.asu.edu. Stories about DSOC can be found at nasa.gov/technology.

Additional information about launch windows (the potential times each day Psyche can launch) can be found at go.nasa.gov/3seZc18.

Interviews with team members from the Psyche mission and the DSOC experiment may be arranged by calling the JPL newsroom at 818-354-5011 or filling out this form.

Video and Images

A Psyche mission media reel, including shots of DSOC, is available at go.nasa.gov/3scwga6.

A collection of Psyche videos is also available at bit.ly/psycheplaylist.

Additional images related to the Psyche mission and the DSOC experiment are available at the NASA Image and Video Library, Planetary Photojournal, and the gallery section of this press kit.

Read NASA's image use policy.

Read JPL's image use policy.

Media Events

NASA's Psyche mission is the first to a metal-rich asteroid, which is also named Psyche. The agency is targeting a launch period that opens Oct. 5, 2023. The mission will ride to space on a SpaceX Falcon Heavy rocket from NASA's Kennedy Space Center in Florida.

Cruising through space with a super-efficient solar electric propulsion system, the Psyche spacecraft is expected to arrive at the asteroid to begin science operations in 2029. It will orbit this unique world for at least 26 months.

Attached to Psyche is the Deep Space Optical Communications technology demonstration, a NASA experiment that will test optical, or laser, communications beyond the Moon.

How to Watch

News briefings and launch commentary will be livestreamed on NASA Television, NASA+, NASA.gov/live, and YouTube.com/NASA. (On-demand recordings will also be available after the live events have finished on YouTube.)

NASA TV channels are digital C-band signals carried by QPSK/DVB-S modulation on satellite Galaxy-13, transponder 15C, at 127 degrees west longitude, with a downlink frequency of 3920 MHz, vertical polarization, data rate of 18 MHz, symbol rate of 33.5 Mbps and 3/4 FEC. A digital video broadcast-compliant integrated receiver decoder is needed for reception. For more information about NASA TV's programming schedule, visit nasa.gov/ntv.

Live Launch Feed

A live video feed of key launch activities and commentary from Kennedy will be broadcast. The first launch opportunity is targeted for Oct. 5, 2023. On launch day, a "clean feed" of the launch without NASA TV commentary will be carried on the NASA TV media channel.

Audio Only

Audio only of launch coverage will be carried on the NASA "V" circuits, which may be accessed by dialing **321-867-1220, -1240, -1260** or **-7135**. On launch day, "mission audio" – the launch conductor's countdown activities without NASA TV launch commentary – will be carried on **321-867-7135**.

On-Site Media Logistics

Media accreditation for on-site access will have closed for international media on Aug. 29, and will close for U.S.-based media on Sept. 12. Accredited media will have access to Kennedy for launch and pre-launch activities related to NASA's Psyche mission. Closer to launch, NASA will release an events-and-briefing advisory with additional information.

Accredited news media can arrange on-site interviews by calling the Kennedy newsroom at 321-867-2468. Media without credentials can call the Kennedy newsroom to see if off-site interviews can be arranged.

Public Viewing Locations

There are launch viewing sites on Florida's Space Coast that are open to the public. More information is available at nasa.gov/centers/kennedy/launchingrockets/viewing.html.

Additional Resources on the Web

Additional detailed information about the Psyche mission is available at nasa.gov/psyche, beta.science.nasa.gov/mission/psyche, and psyche.asu.edu/.

Additional information about the DSOC technology demonstration is available at jpl.nasa.gov/missions/dsoc.

Social Media

Join the conversation and get updates from these accounts:

- **X:** @NASAJPL, @NASASolarSystem, @NASA_technology, @NASASCaN, @NASA
- **Facebook:** NASAJPL, NASASolarSystem, NASATechnology, NASASCaN, NASA
- **Instagram:** @NASAJPL, @NASA, @nasasolarsystem

Quick Facts

Mission Name

Psyche

The name of an asteroid orbiting the Sun in the main asteroid belt between Mars and Jupiter, as well the name of NASA's mission to explore that asteroid. The asteroid Psyche is named after the goddess of the soul in ancient Greek mythology.

Image credit: NASA/JPL-Caltech

Spacecraft

Spacecraft dimensions

The full flight system, including the spacecraft's two five-panel solar arrays, is about the size of a singles tennis court: 81 feet (24.76 meters) long by 24 feet (7.34 meters) wide.

Chassis dimensions

The spacecraft body, or bus, is 16.1 feet (4.9 meters) tall, including the 6.6-foot (2-meter) booms for two science instruments, 7.1 feet (2.2 meters) wide, and 7.8 feet (2.4 meters) deep.

Mass

At launch, the Psyche spacecraft is expected to have a mass of up to 6,056 pounds (2,747 kilograms), including the Deep Space Optical Communications (DSOC) technology demonstration attached to it. The total mass at launch, including the rocket, is 3.16 million pounds (1.43 million kilograms) – more than 99% of which is accounted for by the rocket.

Payload instruments

Psyche has three dedicated instruments – a gamma-ray and neutron spectrometer, a multispectral imager, and a magnetometer. It will also use the X-band radio telecommunications system for gravity science.

Power

Two five-panel, cross-shaped solar arrays power everything on board, including the science instruments. The solar arrays will produce 21 kilowatts when leaving the Earth and between 2.3 and 3.4 kilowatts during orbit around the asteroid.

Propulsion

Psyche uses solar electric propulsion. The spacecraft has four Hall-effect thrusters that rely on electromagnetic fields to expel charged atoms, or ions, of inert xenon gas that in turn create thrust, trailing a blue glow of xenon. Only one thruster is on at a time, providing up to 240 millinewtons of thrust – about the amount of force that one AA battery would exert on the palm of your hand. Psyche will carry seven roughly 22-gallon (82-liter) tanks of xenon propellant – up to 2,392 pounds (1,085 kilograms).

Launch

Targeted launch period

Oct. 5 through 25. Updates on the launch date can be found on the mission's launch blog.

Targeted launch windows

A Psyche launch on Oct. 5 would occur at 10:34 a.m. EDT (7:34 a.m. PDT). Additional information about launch windows (the times each day Psyche can launch) can be found at go.nasa.gov/3seZc18.

Launch site
Launch Complex 39A, NASA's Kennedy Space Center, Florida

Launch vehicle
SpaceX Falcon Heavy rocket

Spacecraft's distance to travel to Psyche
About 2.2 billion miles (3.6 billion kilometers)

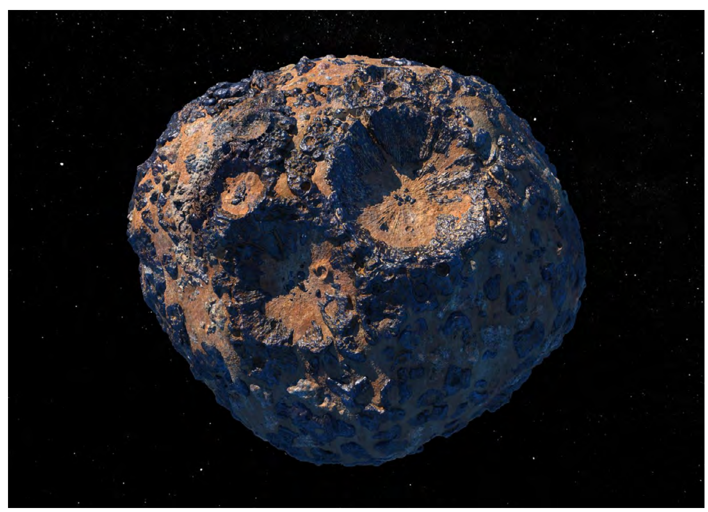
Flight time to Psyche
About 6 years

Launch Ride-Along

The Deep Space Optical Communications (DSOC) experiment
Attached to Psyche is NASA's first test of high-bandwidth optical communications between Earth and distances far exceeding the Moon. It will use a near-infrared laser to send and receive test data between Earth and deep space from November 2023 and October 2025.

Asteroid

Location
The asteroid Psyche orbits the Sun in the outer part of the main asteroid belt between Mars and Jupiter, and it is approximately three times farther from the Sun than Earth is. Track the asteroid's current location with NASA's Eyes on Asteroids.



History
The asteroid was discovered in 1852 by Italian astronomer Annibale de Gasparis. Because it was the 16th asteroid to be discovered, it is sometimes referred to as 16 Psyche.

Name

The asteroid was named for the goddess of the soul in ancient Greek mythology, often depicted as a butterfly-winged female figure.

Size

Psyche has an irregular potato shape. If the asteroid were sliced in half horizontally at the equator – picture a squished oval – it would measure 173 miles (280 kilometers) across at its widest point and 144 miles (232 kilometers) long. It is estimated to have a surface area of about 64,000 square miles (165,800 square kilometers).

Composition

Psyche is likely a mixture of rock and metal, with metal making up between 30% to 60% of its volume.

Psyche Mission Milestones

October 2023

The Psyche spacecraft is scheduled to launch from NASA's Kennedy Space Center in Florida on a SpaceX Falcon Heavy rocket.

May 2026

The spacecraft is expected to fly by Mars, using the planet's gravity as a slingshot to increase velocity.

Late July 2029

If all goes as planned, the asteroid Psyche's gravity will capture the spacecraft after a journey of about 2.2 billion miles (3.6 billion kilometers).

August 2029 to November 2031

The spacecraft conducts its prime mission, gathering science data while orbiting the asteroid.

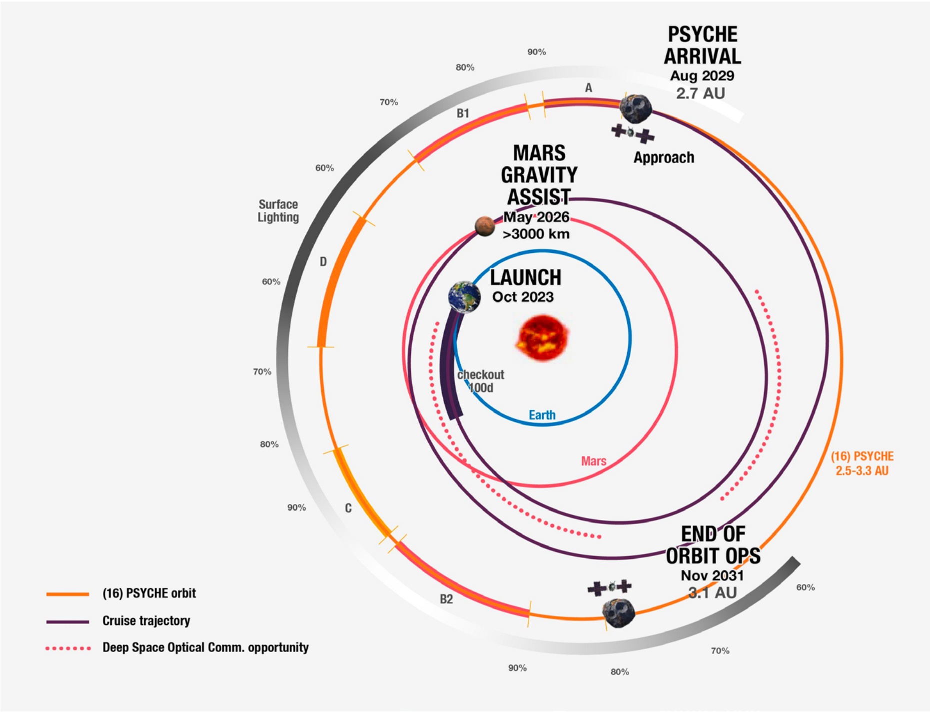
Program

NASA has invested approximately $1.2 billion to develop, launch, and operate the Psyche mission. This includes about $131 million in launch services for Psyche and the Deep Space Optical Communications (DSOC) technology demonstration.

The cost for developing and operating DSOC is about $206 million.

Mission: Overview

The launch period for the Psyche spacecraft is targeted to open Oct. 5, 2023. It will launch from NASA's Kennedy Space Center in Florida on a journey to the metal-rich asteroid of the same name. It is expected to fly by Mars in the spring of 2026 and use the Red Planet's gravity to swing itself toward the outer part of the main asteroid belt, where the asteroid Psyche orbits. In August 2029, after a six-year journey of about 2.2 billion miles (3.6 billion kilometers), the spacecraft will start orbiting the asteroid for at least 26 months.



Seen from above the plane of the planets in this illustration, the Psyche spacecraft takes a spiral path to the asteroid Psyche, with key milestones in its prime mission indicated. The test periods for the Deep Space Optical Communications technology demonstration are indicated with dots. After Psyche is captured by the asteroid's gravity, it will begin orbits of different altitudes and with different science goals (named A, B1, D, C, and B2). Credit: NASA/JPL-Caltech Credit: NASA/JPL-Caltech

Full Image Details

Launch

Psyche will lift off from Launch Pad 39A at Kennedy aboard a SpaceX Falcon Heavy rocket, procured by NASA's Launch Services Program.

Psyche will launch with a NASA ride-along: the Deep Space Optical Communications (DSOC) technology demonstration, which is attached to the Psyche spacecraft but is an experiment separate from the Psyche mission.

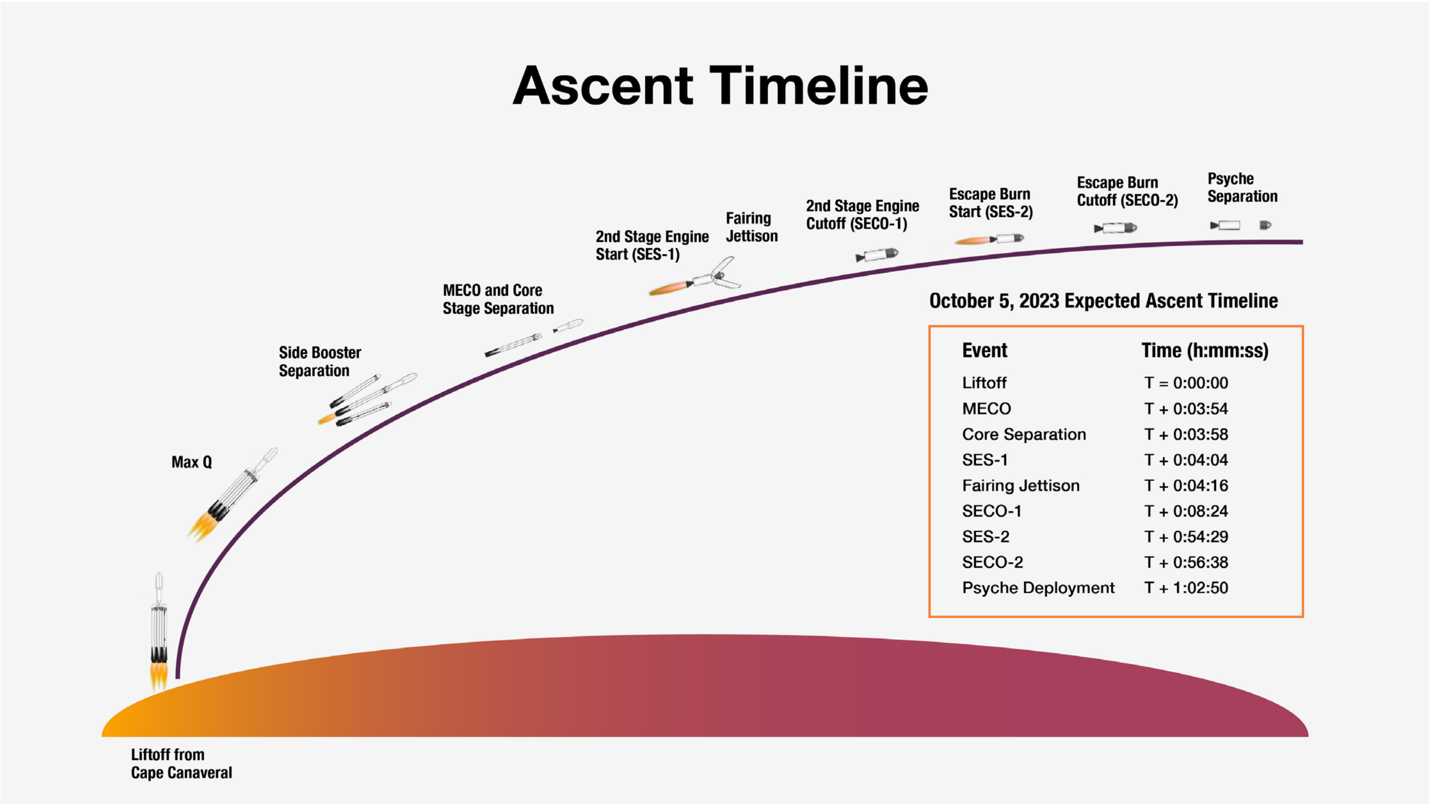
Psyche's launch period opens Oct. 5, with opportunities through Oct. 25. A Psyche launch on Oct. 5 would occur at 10:34 a.m. EDT (7:34 a.m. PDT). The launch window for each day is "instantaneous," meaning that the mission would launch at an exact time or reset for the next day. For the length of the launch period, the expected launch times generally vary only up to about a half-hour.

The spacecraft's journey to the asteroid Psyche requires meticulous planning. Because the spacecraft will rely on a flyby of Mars to slingshot it out toward the asteroid Psyche, the mission team must factor in the movement of Earth and Mars around the Sun. Earth and Mars align closely only about once every 26 months. Determining the range of possible launch dates depends on this planetary clockwork, plus several other factors: the rocket's power, the Psyche spacecraft's mass, the thrust of the spacecraft's propulsion system, and the desired geometry and timing of the Mars flyby as well as the desired start of orbits around the asteroid. All dates in the launch period will allow for the gravity of the asteroid Psyche to capture the spacecraft around late July 2029 and for the mission to begin its science campaign in August 2029.

Launch Sequences

Psyche is the first in a series of scientific missions from NASA and its partners to be launched on a SpaceX Falcon Heavy rocket. Over the next three years, the Falcon Heavy will give a ride to NOAA's GOES-U (a collaboration with NASA), as well as NASA's Europa Clipper, and Nancy Grace Roman Space Telescope. Psyche is the second interplanetary mission SpaceX has launched on behalf of NASA.

The Falcon Heavy is a two-stage rocket with side boosters. After the side boosters separate and return to land, the main engine cuts off. The core stage is then expended into the Atlantic Ocean. At that point, the second stage of the rocket will fire its engine. The second stage helps Psyche escape the grip of Earth's gravity.



Event	Time (h:mm:ss)
Liftoff	T = 0:00:00
MECO	T + 0:03:54
Core Separation	T + 0:03:58
SES-1	T + 0:04:04
Fairing Jettison	T + 0:04:16
SECO-1	T + 0:08:24
SES-2	T + 0:54:29
SECO-2	T + 0:56:38
Psyche Deployment	T + 1:02:50

If Psyche launches Oct. 5, 2023, the elapsed time from liftoff through the milestones shown here will be about one hour and three minutes. The actual times of milestones will differ slightly depending on the launch day. Image credit: NASA/JPL-Caltech Full Image Details

Exact timelines will vary by launch date, but separation from the rocket is expected to occur a little over an hour after liftoff. If Psyche launches on Oct. 5, for instance, the spacecraft would separate from the rocket about an hour and three minutes after liftoff.

After separating from the Falcon Heavy rocket, Psyche will power up its miniature inertial measurement unit (MIMU) to sense if the spacecraft is rotating. The MIMU will help the spacecraft stop any rotation before the next key step: deploying the two cross-shaped solar arrays, each of which consists of five panels.

The spacecraft begins deploying the solar arrays within about six minutes after separation. Stowed flat against opposite sides of the spacecraft, the arrays will unfold one at a time. Each will take about two minutes to release hold-downs that keep them in their stowed position, and about six minutes to unfold and lock into their final position. The pair is expected to be fully deployed in about 21 minutes. Then the spacecraft will start searching for the Sun and reorient itself so that the solar arrays, which spin on a central axis, directly face the Sun.

Once the solar arrays are deployed, the spacecraft will also command itself into "safe mode." In this mode, the spacecraft points one of its low-gain antennas at Earth for communications and completes only minimal engineering activities, awaiting further commands from mission controllers on Earth.

Psyche may be able to connect with these mission controllers and provide real-time data as early as about five minutes after spacecraft separation, before initiating the deployment of its solar arrays. But the best chance for catching Psyche's signal on Earth will occur after deployment is complete, during the safe mode period when the spacecraft is rotating like a rotisserie. It could take up to two hours after separation from the rocket before the first signal is received.

Two of NASA's Deep Space Network facilities will be tracking the Psyche spacecraft around the time of launch. The complex in Canberra, Australia, is expected to come into the spacecraft's line of sight shortly before the spacecraft separates from the launch vehicle. The Goldstone complex near Barstow, California, is expected to come into the spacecraft's view between 20 and 36 minutes after Psyche separates from the rocket. The Canberra complex is expected to pick up the signal first.

Initial Checkout

An initial checkout phase begins when mission controllers have confirmed that Psyche is drawing power from its solar arrays, operating at an appropriate temperature, and engaging in two-way communications with Earth. This phase should begin several hours after liftoff and end about 100 days after launch.

A key purpose of initial checkout is to make sure the flight and ground systems are ready for the spacecraft's thrusters to begin continuously firing. Checkout of the propulsion system is expected to begin several days after launch and include intermittent short and long firings of all four thrusters, with mandatory checkouts completed around six weeks after launch. Another purpose of this phase is to verify the ground team's ability to control, monitor, and operate the spacecraft every day.

Once those primary goals are met, the team will focus on a number of secondary goals, including making sure the flight systems are healthy in preparation for cruising to the asteroid and for calibrating the science instruments.

While most instrument activities occur after the propulsion checkout, three will take place during the early part of the checkout period. The magnetometer, which observes changes in the spacecraft's magnetic field during its checkout activities, is expected to be activated in the first few days after launch. Heaters that help the gamma-ray spectrometer and the imager reach a steady state in the dry, cold conditions of space will also be turned on several weeks after launch.

Active checkout of all the science instruments starts about six weeks after launch. This is the period when the imager will take its first images for calibration purposes, targeting standard stars and a star cluster at a variety of exposures, with several different filters. After this initial checkout of the instrument, the Psyche team will start an automatic feed of raw images to the website go.nasa.gov/3sdfRIN for the duration of the mission.

The first opportunity to power on the Deep Space Optical Communications (DSOC) technology demonstration is expected to come about 20 days after launch, when Psyche remains fairly close to Earth (about 4.7 million miles, or 7.5 million kilometers, away). More information on the technology demonstration is available in the DSOC section.

Cruise

Psyche's cruise phase begins about 100 days after launch, when the spacecraft is ready to fire its thrusters nearly continuously. This phase lasts more than five years as the spacecraft journeys to the metal-rich asteroid. Along the way, there will be periodic flight software updates as well as maintenance and calibration activities for the science instruments and engineering systems. The DSOC experiment will also perform its valuable technology demonstration for future missions during this phase.

Cruise is divided into three parts: Cruise 1, Mars Gravity Assist, and Cruise 2.

Cruise 1 covers the trajectory from Earth to Mars and requires extended use of Psyche's thrusters to get on track to meet up with Mars on time. If all goes as planned, Cruise 1 begins 100 days after launch and ends 60 days before the flyby of Mars in May 2026.

Psyche will be flying relatively close to Mars for what is called a gravity assist: Harnessing the planet's gravity, Psyche will use the speed at which Mars travels around the Sun to increase the spacecraft's own speed and change its direction without using much propellant. This effect is similar to how a ball thrown at a moving train will bounce off the train in another direction at a higher speed. If Psyche launches early in its launch period, the spacecraft will be traveling at about 45,600 mph (102,800 kph) relative to the Sun five days before the Mars flyby. Five days after the closest approach to Mars, Psyche will be traveling about 52,200 mph (104,900 kph) relative to the Sun.

During the Mars Gravity Assist period, Psyche will mostly turn off its thrusters and coast to Mars. Because the performance of each thruster can vary slightly, precision navigation to Mars will be easier with the thrusters off. Engineers will restart them for short periods to complete what are known as "Mars trim maneuvers" to bring the spacecraft closer to the Red Planet.

Psyche's close approach to Mars will be in May 2026, although the exact date and the exact altitude above the planet vary slightly based on when Psyche launches. (Possible dates of closest approach throughout the launch period all fall in May 2026.) The spacecraft is expected to fly between about 1,900 to 2,700 miles (3,000 to 4,400 kilometers) above Mars – a safe distance above the planet yet close enough to get a gravity assist. Psyche will likely be traveling at about 13,000 mph (21,000 kph) relative to the surface of Mars.

Two days after the Mars gravity assist, the spacecraft will begin Cruise 2, an approximately 29-month journey requiring near-continuous use of its thrusters. Cruise 2 ends as the orbiter starts its approach to the asteroid Psyche in the spring of 2029.

As the spacecraft cruises to the asteroid, the Sun will block the spacecraft's view of Earth for several days. During this period, known as solar conjunction, Psyche will not be able to communicate reliably with mission controllers, but the spacecraft is programmed to get closer to the asteroid without having to communicate with Earth. The first conjunction is expected to occur for 10 days in September 2024.

Approach to Asteroid Psyche

The spacecraft's slow, careful approach to the asteroid Psyche is expected to begin in May 2029, allowing the team to make refinements based on what they discover about the asteroid's gravity field, shape, and spin. This phase starts about 100 days before the spacecraft initiates its first orbit designed for gathering science data (Orbit A).

Psyche's imager will play a key role during the approach, providing images for navigation as well as for science. The first image for optical navigation, when asteroid Psyche will appear as a speck of light only a few pixels wide, is expected in early May 2029.

Using its gentle solar electric propulsion system, the spacecraft will position itself to be captured by the asteroid's gravity. This is expected to occur in late July 2029. By the time spacecraft has been captured by the asteroid's gravity, the asteroid Psyche will have gone from appearing as just a few pixels in an image to being about 500 pixels across in what will be the first close-up images of this metal-rich world.

Over the next 20 days, the Psyche spacecraft will maneuver into its first of four orbits. By that point, the final checkouts and calibration of all three science instruments and the gravity science investigation will be complete. Now the mission can study the asteroid.

Orbital Operations

If all goes as planned, the mission's orbital operations phase will start in August 2029, lasting at least 26 months. Through a series of circular orbits that go lower and then higher in altitude around Psyche, which is about 173 miles (280 kilometers) at its widest point, the spacecraft will map the asteroid and gather science data. (Read about the main science goals of the mission in the science section.)

The orbits are named alphabetically by highest (A) to lowest (D), but they don't proceed in alphabetical order. Rather, they proceed based on the changing amount of sunlight illuminating the asteroid's surface during observation and the kind of science that can be done. The mission has also built buffer ("margin") into its orbital operations timeline in case engineers need to address operational issues. The timing below should be considered approximate and subject to change as the team visits this unexplored world.

Orbit A, the first orbit, is expected to last about 56 days, from August to October 2029, at about 441 miles (709 kilometers) above the surface. The mission will focus on imaging and mapping the asteroid while taking magnetic field and gravity measurements.

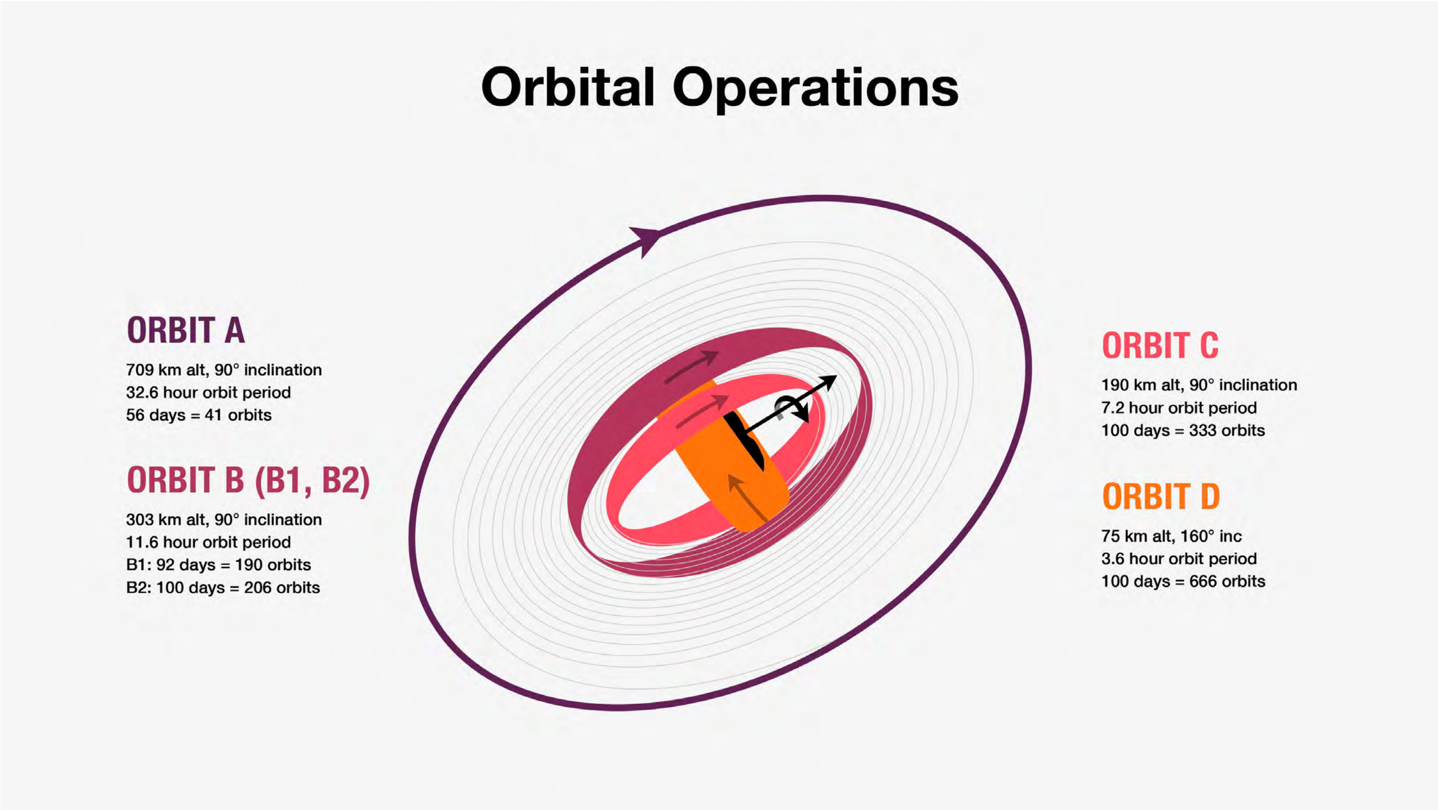
Between each orbit, the spacecraft will need to change altitudes. During the first "transfer" after Orbit A, Psyche will take 17 days to descend to 188 miles (303 kilometers) above the surface for the first segment of Orbit B in late October 2029.

During Orbit B, the mission will focus on mapping the topography and geology of at least 80% of the asteroid while also continuing to assess the asteroid's magnetic field and gravity. Because sunlight will illuminate less and less of the asteroid's surface when the first part of Orbit B begins, this orbit is split into two parts, B1 and B2, so that the spacecraft can complete its mapping requirement. Orbit B1 will last about 92 days, until late January 2030. The spacecraft will return to the same altitude for B2 in May 2031, when more of the asteroid is bathed in sunlight again.

The mission will take up to 98 days to transfer to Orbit D, the lowest in altitude, which brings the spacecraft within 47 miles (75 kilometers) of the asteroid's surface. At the same time, Orbit D marks a shift from a course that generally goes around the asteroid's poles to one that generally travels around its equator. This orbit will help the mission focus on measuring the asteroid's composition. The spacecraft will also map the asteroid and study its gravity and magnetic field. With about a month built in as a buffer, Orbit D is expected to start in May 2030 and last about 100 days.

Transferring into Orbit C in mid-January 2031 (based on current expectations), at an altitude of 118 miles (190 kilometers), the spacecraft will shift back to an orientation around the asteroid similar to Orbits A and B. This orbit will measure topography and perform the highest-priority magnetic field and gravity measurements of the prime mission.

At this point, when sunlight returns to illuminating about 80% of the asteroid's surface, the spacecraft will move into Orbit B2, traveling around Psyche at an altitude of 188 miles (303 kilometers) for about 100 days.



The spacecraft's science-gathering operations take place at four orbit altitudes above the asteroid, with one orbit (Orbit B) split into two parts.

Image credit: NASA/JPL-Caltech Full Image Details

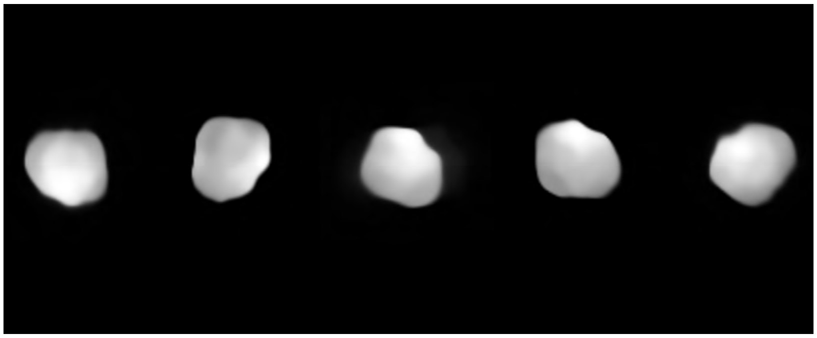
The Psyche team has built in an additional 67 days of margin at the end of the prime mission that can be used to provide extra time for unexpected operational needs or science gathering. Psyche's prime mission is currently anticipated to end on Nov. 1, 2031.

Mission: Science

More than 150 years have passed since novelist Jules Verne wrote "Journey to the Center of the Earth," but reality has yet to catch up with that science fiction adventure. While humans can't bore a path to our planet's metallic core, NASA's Psyche mission will visit a giant asteroid that may be the solidified remains of the molten core of a bygone world.

The asteroid Psyche orbits the Sun in the main asteroid belt between Mars and Jupiter. Using data gathered from Earth-based radar and optical telescopes, scientists hypothesize that Psyche is a metal-rich asteroid. It could be part or all of the iron-rich interior of a planetesimal, an early planetary building block, that was stripped of its outer rocky shell as it repeatedly collided with other large bodies during the early formation of the solar system.

The asteroid, which is about 173 miles (280 kilometers) at its widest point, could also be the leftover piece of a completely different kind of object that formed from metal-rich material somewhere in the solar system.



A representative image of the best views scientists have of the asteroid Psyche, obtained by the European Southern Observatory in 2018. Psyche expects to have much crisper, more detailed images of the asteroid as the spacecraft begins its approach.

Image credit: ESO/LAM Full Image Details

The first mission to explore an asteroid with a surface that contains substantial amounts of metal rather than rock or ice, Psyche seeks to better understand iron cores, an unexplored building block of planet formation.

The mission will be the first to directly examine the interior of a previously layered planetary body, which they expect will shed additional light on how Earth and other rocky planets formed.

Science Goals and Objectives

Each NASA mission has a set of science goals – larger areas of knowledge that it must contribute to – and a set of science objectives, which are specific, measurable actions to complete.

The science goals for Psyche are to:

- Understand iron cores, a previously unexplored building block of planet formation.
- Look inside terrestrial planets, including Earth, by directly examining the interior of a differentiated (layered) body, which otherwise could not be seen.
- Explore a new type of world – one made not of rock and ice, but significant amounts of metal.

Psyche's more specific science objectives are:

- Determine whether the asteroid Psyche is a planetary core or if it is unmelted material.
- Determine the relative ages of regions of Psyche's surface.
- Determine whether small metal bodies incorporate the same light chemical elements (including sulfur, potassium, and silicon) that are expected to be present in Earth's high-pressure core.
- Determine whether Psyche was formed under conditions more oxidizing or more reducing than Earth's core. In Psyche's case, these terms refer to whether there is a lot of oxygen present in the asteroid's metal compounds (oxidized) or little to no oxygen (reduced). Answering this question will help to determine the conditions of the environment in which Psyche formed.
- Characterize Psyche's topography.

What Do We Know About the Asteroid Psyche?

Until recently, the scientific consensus was that the asteroid Psyche consisted mostly of metal. New information on density, radar properties, and spectral signatures indicate that the asteroid is possibly a mix of metal and silicate minerals. There are still contradictions in the data, but the best analysis indicates that Psyche is likely made of a mixture of rock and metal, with metal composing 30% to 60% of its volume. The asteroid's metal content is estimated based on its density, how much visible light and radar are reflected by the asteroid, and by the measurements of the asteroid's thermal inertia (how quickly it gains or re-radiates heat).

By combining radar and optical observations, scientists have generated a 3D model of Psyche that gives us an idea of the general shape of the asteroid and even shows evidence of two craterlike depressions. The data also suggest that there is significant variation in the metal content and color of the asteroid over its surface. But until this mission sees the asteroid Psyche up close for the first time, we will not know what it looks like in detail.

How was the asteroid formed?

Scientists think Psyche may consist of significant amounts of metal from the core of a planetesimal, one of the building blocks of our solar system. The asteroid is most likely a survivor of multiple violent hit-and-run collisions, common when the solar system was forming. Thus, Psyche may be able to tell us how Earth's core and the cores of the other rocky, or terrestrial, planets came to be.

What is its size, shape, density, and gravity?

The shape of the asteroid Psyche is irregular and potatolike. If it were sliced in half horizontally at the equator – picture a squished oval – the asteroid would measure 173 miles (280 kilometers) across at its widest point and 144 miles (232 kilometers) long. Its surface area is 64,000 square miles (165,800 square kilometers).

Psyche is dense, estimated at about 212 to 256 pounds per cubic foot (3,400 to 4,100 kilograms per cubic meter). The surface gravity on Psyche is much less than it is on Earth or even the Moon. On Psyche, lifting a car would feel like lifting a large dog.

What kind of orbit is the asteroid Psyche in?

Psyche follows an orbit in the outer part of the main asteroid belt, between Mars and Jupiter, at an average distance from the Sun of 3 astronomical units, or AU (about 280 million miles, or 450 million kilometers). Earth orbits at 1 AU (about 93 million miles, or 150 million kilometers). Because Psyche and Earth orbit at different speeds, the distance from Earth to Psyche varies over a large range, from less than 2 AU to greater than 4 AU.

Where is asteroid Psyche now?

Track the asteroid's location with NASA's Eyes on Asteroids.

Is NASA mining Psyche or other asteroids?

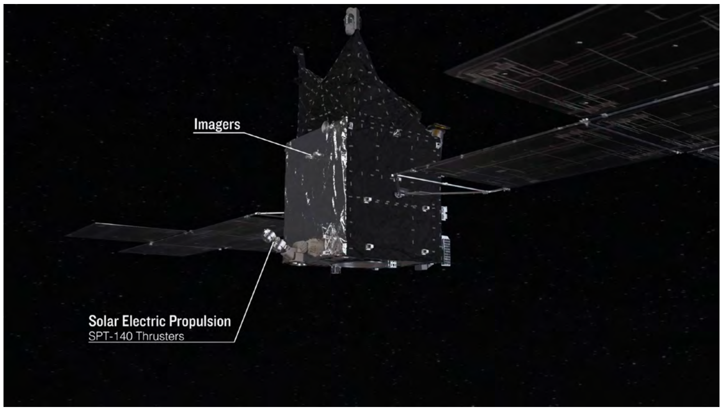
No, NASA is not mining asteroids. Psyche is a fundamental science research mission that is looking to understand more about asteroids.

Principal Investigator Lindy Elkins-Tanton answers an oft-asked question from the public. bit.ly/459IYoz

Science Team Leadership

Psyche is a science-led mission helmed by Principal Investigator Lindy Elkins-Tanton of Arizona State University (ASU) in Tempe. The deputy principal investigator is Ben Weiss of the Massachusetts Institute of Technology (MIT) in Cambridge.

Science Instruments and Investigations

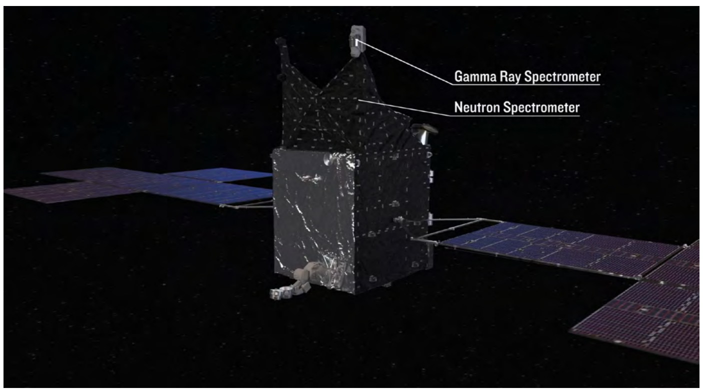


Multispectral Imager

Psyche's multispectral imager consists of a pair of identical cameras equipped with filters and telescopic lenses to photograph the surface of the asteroid in different wavelengths of light. The cameras can take pictures in the part of the spectrum visible to the human eye, as well as in near-infrared wavelengths of light beyond what humans can see. The images will help the science team learn about the mineral composition of Psyche; map the distribution of craters, valleys, cliffs, and other geologic features; and enable the creation of 3D topographic maps – all of which will provide clues to Psyche's history.

The imager operations team is based at ASU. Jim Bell is the imager team lead, David Williams is the deputy lead, and Michael Walworth is the imager operations lead.

Gamma-Ray and Neutron Spectrometer

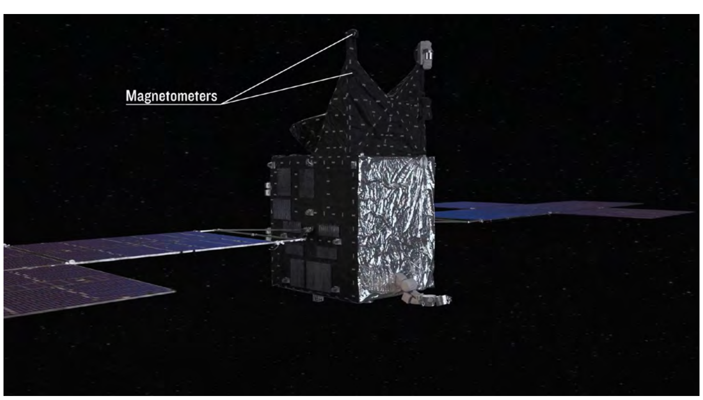


The orbiter's gamma-ray and neutron spectrometer (GRNS) will help scientists determine the chemical elements that make up the asteroid's surface material. As cosmic rays and high energy particles bombard the asteroid Psyche's surface, the elements there absorb the energy. In response, they emit neutrons and gamma rays of varying energy levels. The spectrometer can detect these emissions, enabling scientists to match them to properties of known elements to determine what Psyche is made of.

The team is based at the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland. David Lawrence is the GRNS lead, and Michael Cully is the GRNS project manager.

A video about the instrument can be found at youtu.be/P7KcRWrUS5E.

Magnetometer

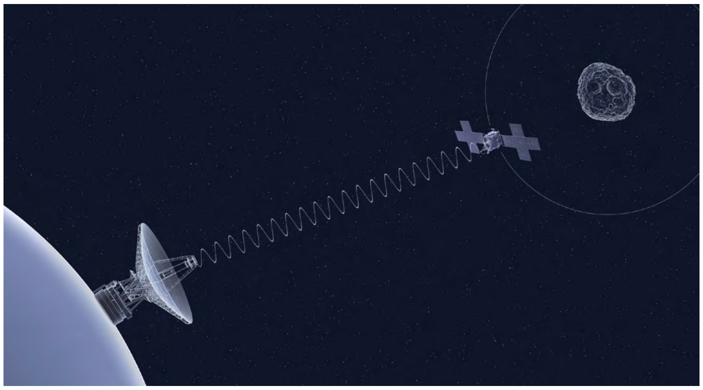


The orbiter's magnetometer will look for evidence of an ancient magnetic field at the asteroid Psyche. Unlike Earth and other rocky planets that generate a magnetic field in their liquid metallic cores, small bodies like asteroids do not generate one because they are frozen. If the magnetometer detects an intrinsic field around the asteroid, it would be from remanent, or residual, magnetization – electrons that were aligned in Psyche's materials when they cooled in an ancient field generated in the body's molten core billions of years ago before that core cooled. Confirmation of a remanent magnetic field would be strong evidence that the asteroid formed from the core of a planetary body.

The instrument's team is based at MIT in Cambridge, where Ben Weiss is the magnetometry investigation lead, and Technical University of Denmark (DTU) in Lyngby, where José Merayo is the chief magnetometer designer and co-investigator at DTU Space.

A video about the instrument can be found at youtu.be/uxVc2VEPff0.

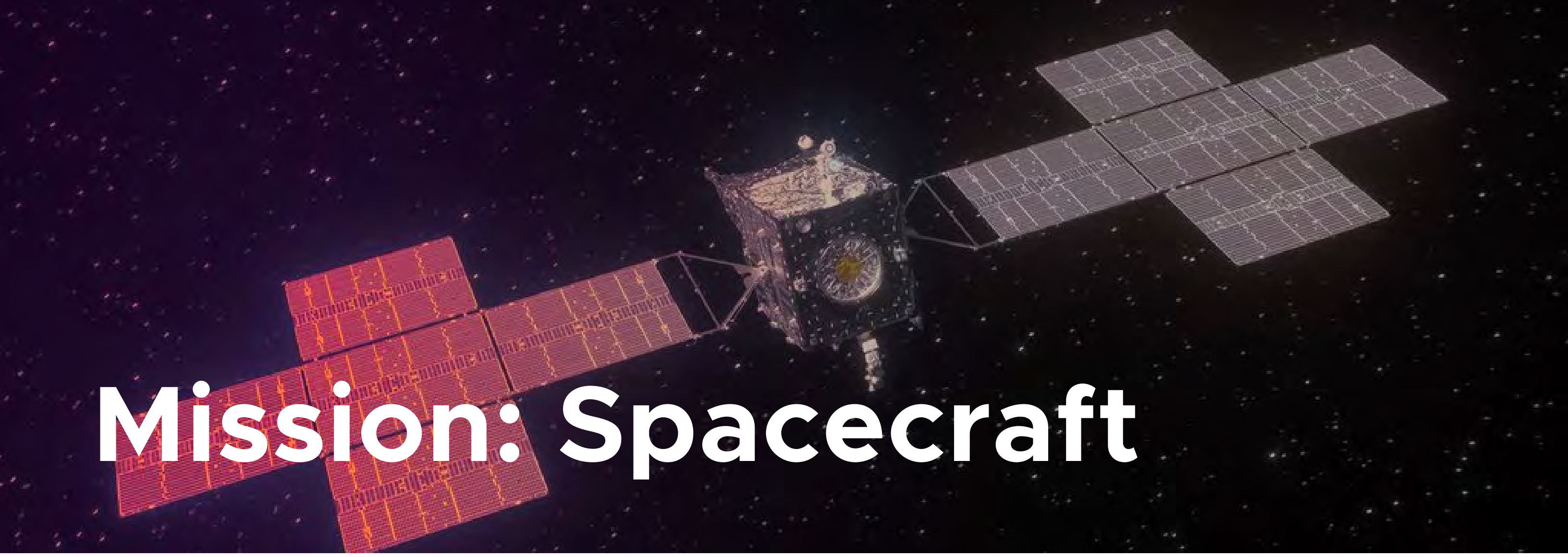
Gravity Science



The Psyche science team will rely on the telecommunications system, used to send commands to and receive data from the spacecraft, to conduct gravity science also. By analyzing the X-band radio waves the spacecraft communicates with, scientists can measure how Psyche affects the spacecraft's orbit.

From that information, scientists can determine the body's rotation, mass, and gravity field, providing additional clues about the composition and structure of Psyche's interior. Unlike Earth, Psyche is far from round. Measuring the gravity field is important so that the navigation team can safely fly the spacecraft close to the surface and provide detailed and accurate scientific measurements.

The team is based at MIT and NASA's Jet Propulsion Laboratory in Southern California. Maria Zuber of MIT is the gravity science investigation lead, and Ryan Park of JPL is the deputy lead.



Mission: Spacecraft

Psyche combines brains built by NASA with off-the-shelf components used in Earth-orbiting commercial satellites: The main computer, flight software, fault-protection systems, and most of the telecommunications systems come from NASA's Jet Propulsion Laboratory in Southern California, while a Palo Alto, California, division of Colorado-based Maxar Technologies provided the main body of the spacecraft and most of its engineering hardware systems.

The body, or spacecraft bus, has a rectangular, panel-box construction supported by an internal central cylinder of graphite composite. It is an enhanced, modified version of Maxar's 1300 satellite bus from a family of long-lasting, powerful communications satellites that have been sent into Earth orbit for more than 30 years but have never gone to deep space.

For this mission, to enable the Maxar bus to support the payload and travel to the cold and dark of the asteroid belt, the spacecraft's temperature is regulated with thermal blanketing, embedded heat pipes, multilayer insulation, heaters, about 300 temperature sensors, and thermal louvers over the radiator surfaces that open and close like Venetian blinds to release heat and limit cooling.

The full flight system, including the spacecraft's twin five-panel solar arrays, is about the size of a singles tennis court: 81 feet (24.76 meters) long by 24 feet (7.34 meters) wide. The bus is about 16.1 feet (4.9 meters) tall, including the 6.6-foot (2-meter) booms for two of the instruments; 7.1 feet (2.2 meters) wide; and 7.8 feet (2.4 meters) deep.

Excluding propellant, Psyche is expected to weigh up to 3,563 pounds (1,616 kilograms) at launch.

Propulsion

Similar to NASA's past Dawn and Deep Space 1 missions, Psyche uses solar electric propulsion, which relies on large solar arrays to generate power for the entire flight system, including the spacecraft's thrusters. Those thrusters employ a combination of electric and magnetic fields to accelerate and expel charged atoms, or ions, of xenon gas that in turn create thrust as they accelerate rapidly away from the craft, emitting a brilliant blue glow.

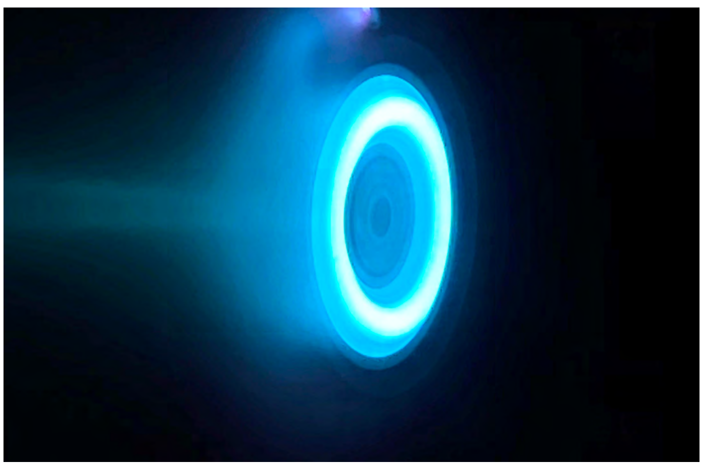


Image credit: NASA/JPL-Caltech

Full image and caption

Inert and easily ionized, the chemical element xenon exists in the air we breathe in tiny amounts, and it is commonly used in car headlights and plasma TVs. Psyche will carry seven roughly 22-gallon (82-liter) tanks of xenon propellant, totaling 2,392 pounds (1,085 kilograms) – more xenon than any previous space mission.

Compared with conventional chemical propulsion, Psyche's incredibly efficient solar electric propulsion system uses a much smaller amount of propellant and produces a lower amount of thrust, meaning Psyche's acceleration toward its target will be slow. Since the thrusters work nearly continuously during the cruise to Psyche, the speed of the spacecraft will continue to increase – to up to 124,000 mph (200,000 kph) relative to Earth – and can exceed what chemical propulsion systems are capable of. Psyche consumes just 0.35 kilograms to 1.3 kilograms of xenon a day, depending on the thruster power level, and the mission will get the equivalent of nearly 10 million miles to the gallon on its long journey.

Image credit: NASA/JPL-Caltech

Full image and caption

Psyche will be the first spacecraft to use Hall-effect thrusters beyond lunar orbit. (Dawn and Deep Space 1 used ion thrusters; Psyche's thrusters are simpler and more powerful.) The four thrusters are located in two pairs on the bottom of the spacecraft bus. Only one thruster will operate at a time, providing up to 240 millinewtons of thrust – about the amount of force that one AA battery would exert on the palm of your hand. Psyche will spend most of its flight time thrusting toward its target. Once at the asteroid, the orbiter will rely on the thrusters to propel itself through four orbits (one of which has two parts) around the asteroid for the mission's science investigations.

Psyche also has 12 smaller thrusters fueled by a nitrogen cold gas system to help with momentum management around the asteroid and for use when the Hall-effect thrusters aren't fully functional, like when the spacecraft separates from the rocket, when the solar arrays are deploying, and when the spacecraft is in "safe mode" (a precautionary standby status). The spacecraft will carry three 22-gallon (82-liter) tanks of pressurized nitrogen propellant, or about 101 pounds (46 kilograms).

Power

Spacecraft power is provided by twin five-panel, cross-shaped solar arrays that deploy from opposite sides of the spacecraft and spin around a central axis to point at the Sun. To generate sufficient power when Psyche is more than three times farther from the Sun than Earth is, the arrays must be large: about 800 square feet (75 square meters). Each array measures 37.1 feet (11.3 meters) long and 24 feet (7.3 meters) wide.

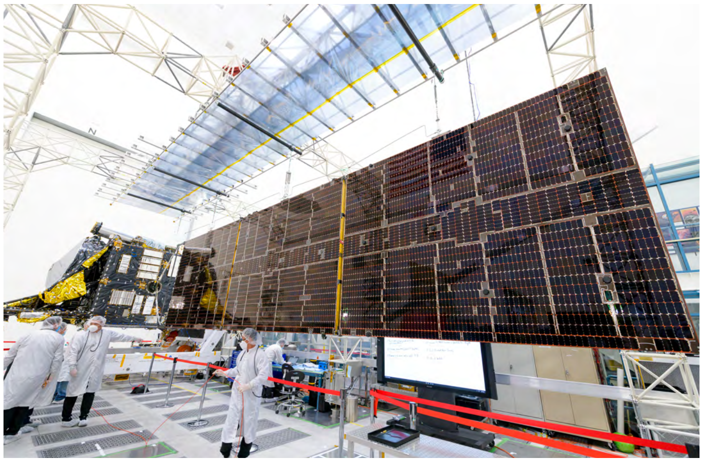
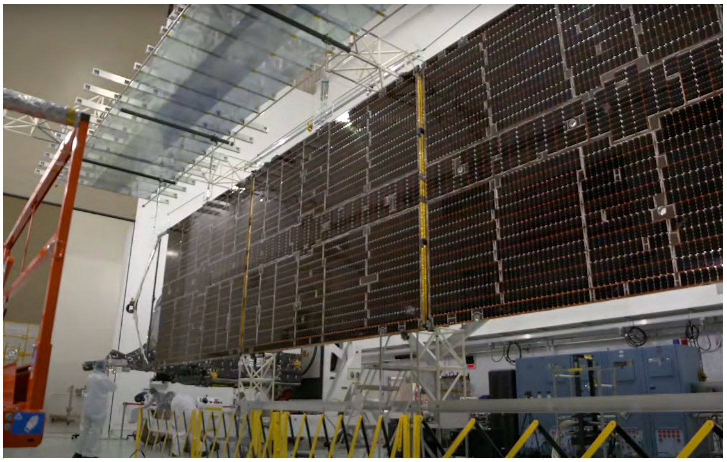


Image credit: NASA/JPL-Caltech
Full image and caption

The arrays power everything on board, including the science instruments. Near Earth, they will generate 21 kilowatts. But after arriving at Psyche, when the asteroid is farthest from the Sun, they'll produce about 2.3 kilowatts – a little more than what's needed to power a hair dryer.



The solar arrays for NASA's Psyche mission underwent a final deployment test and were permanently installed on the spacecraft at Astrotech Space Operations near the agency's Kennedy Space Center in Florida.
bit.ly/3OXpPR6

The underlying technology isn't much different from solar panels installed on a home, but Psyche's 22,730 ZTJ triple-junction photovoltaic cells, provided by SolAero Technologies of Albuquerque, New Mexico, are hyper-efficient, lightweight, radiation resistant, and able to provide more power with less sunlight.

For more on the solar array deployment timeline after launch, go to the mission overview section.

The spacecraft also carries a 144 amp-hour, 13-cell lithium-ion battery that can supply power when the arrays aren't in sunlight or when power needs exceed what's available from the arrays.

Image credit: NASA/JPL-Caltech

Full image and caption

Telecommunications

Psyche will communicate with Earth via its four antennas: one 6.5-foot (2-meter) fixed high-gain antenna provided by Maxar and three small low-gain antennas designed and manufactured by JPL. Together, the antennas will provide nearly full sky coverage. Only one antenna can be used at a time.

Image credit: NASA/JPL-Caltech

Full image and caption

Like all NASA interplanetary missions, Psyche will send data and receive commands via the agency's Deep Space Network (DSN), which has three ground stations equidistant around Earth to talk with and track spacecraft. Psyche will rely on the DSN's 111-foot-wide (34-meter-wide) antennas, communicating in the X-band frequency range, which is on the radio portion of the electromagnetic spectrum. The DSN then routes the data back to Psyche mission controllers through a ground data system at JPL.

While cruising toward the asteroid Psyche, the spacecraft will communicate at least once per week with the DSN. Much more frequent communication will occur as the spacecraft gathers science data and images while orbiting the asteroid.

Image credit: NASA/JPL-Caltech

Full image and caption

All Psyche data – navigation, science, and both spacecraft and instrument engineering telemetry – will be transmitted through its antennas to DSN facilities.

Attached to one side of the spacecraft, the Deep Space Optical Communications (DSOC) technology demonstration will send only test data – optical signals that will go to other Earth ground stations. DSOC is physically aligned with the high-gain antenna on the spacecraft so that Psyche can send its radio and DSOC's optical signals at the same time. More information about DSOC can be found in the DSOC section.

Mission: Planetary Protection

The U.S. has obligations under the international 1967 Outer Space Treaty to explore space in a responsible manner that avoids the harmful contamination of celestial bodies while also not adversely affecting Earth's environment with the return of any extraterrestrial samples. To help meet these obligations, NASA's Office of Planetary Protection draws up cleanliness standards known as planetary protection requirements. These requirements ensure preservation of the integrity of scientific measurements made during solar system exploration by minimizing the chance that microbes or other organic material brought from Earth could be confused with local materials.

Planetary protection categories range from I to V, extending from the fewest protocols to the most. Outbound missions to celestial bodies that may have once held an environment suitable for life – including Mars and outer solar system icy bodies such as Jupiter's moon Europa – fall into Planetary Protection Category III or IV.

Although the asteroid Psyche is not currently considered to be a body that would be a target for future biological study, the Psyche spacecraft is designated as a Planetary Protection Category III mission because it is flying by Mars for a gravity assist. The mission is required to demonstrate a probability of 99% or higher of avoiding impact with Mars for 20 years after launch, and 95% for a period of 20 to 50 years post-launch. When the Psyche mission concludes, the spacecraft's disposal orbit will consist of a long-term, non-impacting trajectory.

To meet NASA's cleanliness standards, engineers assembled the Psyche spacecraft in a clean room. Environmental conditions within the clean room are strictly monitored, and air filters are used that limit the size and number of dust particles. The surfaces and floors of the clean room are frequently treated with strong cleaning solutions to kill and remove living microbes. Mission hardware, including the tools used for spacecraft assembly, is cleaned using techniques that have proven effective on many previous missions without damaging the spacecraft. Technicians working in the clean room must wear "bunny suits," face masks, hair covers, and latex gloves. Before entering, personnel step into an "air shower" that blows stray particles off the outside of their garments.

Management

Bill Nelson is the agency administrator at NASA Headquarters in Washington.

The Psyche mission is sponsored by NASA's Science Mission Directorate, where Nicola Fox is the associate administrator and **Lori Glaze** is the director of the Planetary Science Division. **Bill Knopf** is the Psyche program executive. **Sarah Noble** is the program scientist.

Arizona State University in Tempe leads the Psyche mission and is the home to the mission's principal investigator, **Lindy Elkins-Tanton**. The mission's deputy principal investigator is **Ben Weiss** from the Massachusetts Institute of Technology in Cambridge.

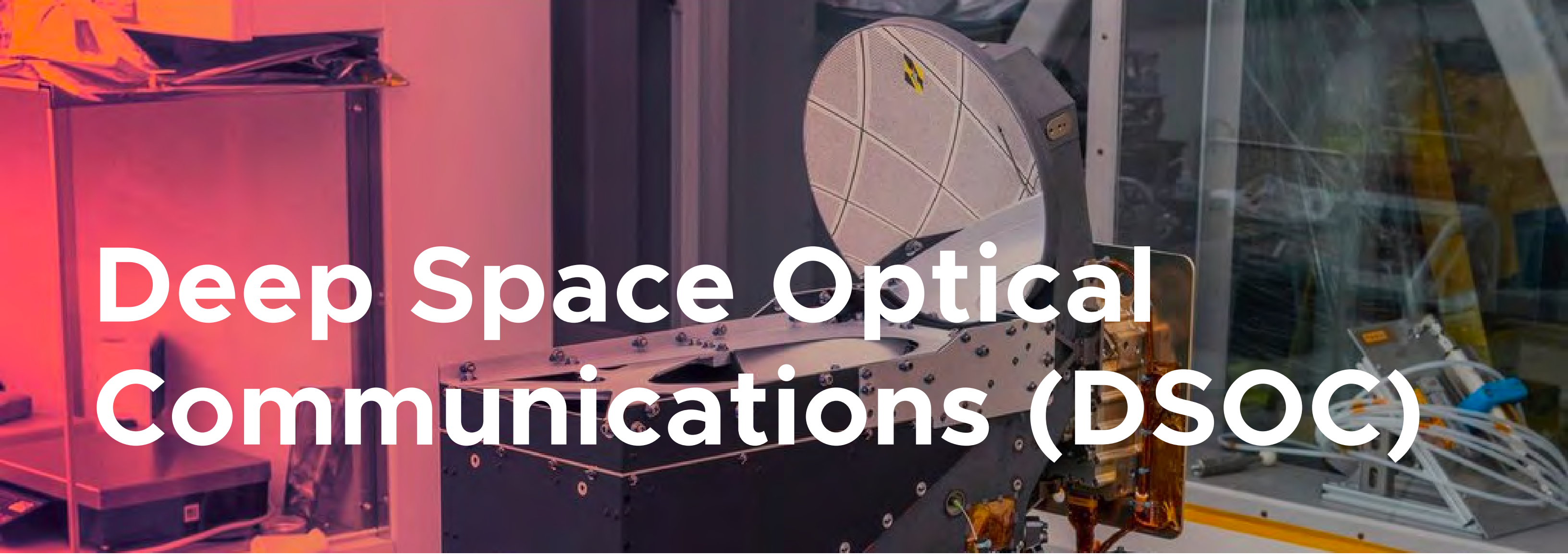
NASA's Jet Propulsion Laboratory, a division of Caltech in Pasadena, California, is responsible for the mission's overall management, system engineering, integration and testing, and operations. At JPL, the project manager is **Henry Stone**, the deputy project manager is **Robert Mase**, and the project scientist is **Carol Polanskey**.

The Deep Space Optical Communications (DSOC) technology demonstration is sponsored by the Technology Demonstration Missions (TDM) program within NASA's Space Technology Mission Directorate (STMD) and the Space Communications and Navigation (SCaN) program within the agency's Space Operations Mission Directorate (SOMD). **Prasun Desai** is the acting associate administrator of STMD. **Kenneth Bowersox** is the associate administrator for SOMD. **Trudy Kortes** is the director of TDM. **Jason Mitchell** is the program executive of SCaN. **Joel Robinson** is the DSOC mission manager.

JPL manages the DSOC project for NASA. JPL's **William "Bill" Klipstein** is DSOC's project manager, and **Abhijit "Abi" Biswas** is the project technologist.

NASA's Launch Services Program, based at the agency's Kennedy Space Center in Florida, is responsible for management of the launch service. For Psyche, **Tim Dunn** is the launch director, and **Serkan Bastug** is the mission manager.

For more details on Psyche team members, visit the Psyche mission team page.



Deep Space Optical Communications (DSOC)

NASA's Deep Space Optical Communications (DSOC) experiment is the agency's first demonstration of laser, or optical, communications from deep space, covering Earth-Mars distances. DSOC is a technology demonstration, which means it will test key technologies that may be used in future missions. While the Psyche spacecraft will provide power to the DSOC flight laser transceiver and help it point at Earth, the experiment is not intended to relay Psyche mission data. DSOC operations are planned for about two years, beginning roughly 20 days after launch.

The DSOC flight laser transceiver can be easily identified by its prominent tubelike sunshade protruding from the side of the Psyche spacecraft, seen here in a clean room at JPL as mission team members prepare the spacecraft for transport. Image credit: NASA/JPL-Caltech

[Full image and credit]

How DSOC Works

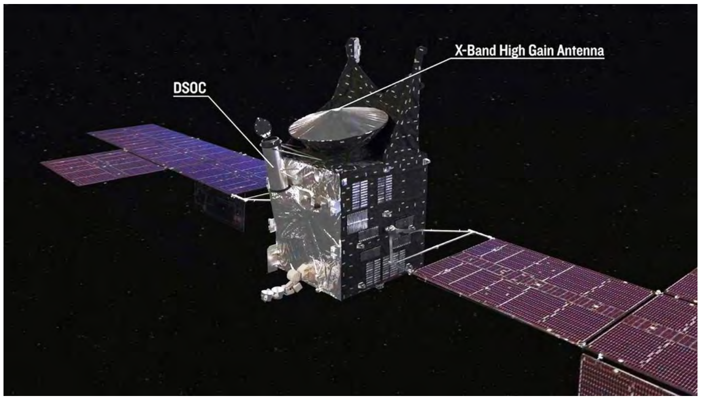
The DSOC system is composed of three elements, all of which incorporate new advanced technologies:

— A near-infrared laser transceiver, attached to the Psyche spacecraft, transmits and receives data through an 8.6-inch (22-centimeter) aperture telescope. The transceiver will transmit high-rate data to Earth using its 4-watt, near-infrared laser and receive low-rate data from Earth using an attached photon-counting camera.

- A high-power (5-kilowatt) ground-based laser transmitter operated from the Optical Communications Telescope Laboratory (OCTL) at JPL's Table Mountain facility near Wrightwood, California, will deliver a beacon and low-rate uplink data to the flight laser transceiver.
- The 200-inch (5.1-meter) Hale Telescope at Caltech's Palomar Observatory in San Diego County, California, will receive the downlinked high-rate data from the DSOC flight laser transceiver during the technology demonstration in the first two years of Psyche's deep space journey.

Laser communication systems come with unique advantages and challenges. Both radio and near-infrared laser communications use electromagnetic waves to transmit data, but near-infrared light packs the data into significantly tighter waves, enabling ground stations to receive more data at once. Using this kind of narrower, more concentrated laser beam from space requires incredibly accurate pointing and tracking to transfer data efficiently to a ground station.

Also, as the distance between the laser transmitter and receiver increases, the laser signal becomes weaker, requiring highly sensitive sensors to detect and record the diminished laser light. Because the laser signal is so weak over large distances, background "noise" – in the form of stray sunlight and scattered light in Earth's atmosphere – can overwhelm the data carried by the few laser photons that arrive at the detector.



This illustration of the Psyche spacecraft shows the locations of the DSOC technology demonstration and X-band high-gain antenna. Image credit: NASA/JPL-Caltech/ASU

To counter these challenges and demonstrate the efficacy of deep space laser communications, DSOC's flight laser transceiver is mounted on an assembly of struts and actuators that stabilize the optics despite spacecraft vibrations. This essentially "decouples" DSOC's flight hardware from the spacecraft, preventing these tiny motions from nudging the pointing of the downlink laser off target. The transceiver's telescope is also fitted with a long cylindrical sunshade (to block stray light from hitting the receiver) that protrudes from the side of the spacecraft body, making it one of Psyche's easily identifiable features.

During operations, the spacecraft will assist the initial coarse pointing of the DSOC flight transceiver by rotating to point the flight transceiver in the general direction of the ground-transmitted beacon at Table Mountain. The DSOC transceiver has the ability to search for and then lock onto the beacon, stabilize its line of sight, and transmit the narrow high-rate data downlink beam to Palomar's 200-inch (5.1-meter) Hale Telescope.

The large-aperture Hale Telescope then collects the faint signal and guides it to a superconducting nanowire photon-counting detector that can precisely measure and process the time of arrival of the photons. Through this back-end signal processing, the data that is modulated and encoded into the laser beam in deep space can be decoded and converted to information on the ground.

Timeline After Launch

The dates below could shift depending on how the Psyche spacecraft's initial checkouts proceed.

- Roughly 20 days after launch: DSOC calibration and commissioning phase is expected to begin, preparing the technology demonstration for operation.
- Roughly 50 days after launch: First expected contact opportunity between DSOC ground systems and the flight transceiver aboard Psyche.
- June 2024: First phase of this technology demonstration ends.
- January 2025: Second phase of the tech demo begins.
- October 2025: DSOC tech demo ends.

The 200-inch (5.1-meter) Hale Telescope at Caltech's Palomar Observatory in San Diego County will receive high-rate data from the DSOC flight laser transceiver and (inset) the ground-based laser transmitter at JPL's Table Mountain will send low-rate data to the flight transceiver. Image credit: NASA/JPL-Caltech/Palomar Observatory

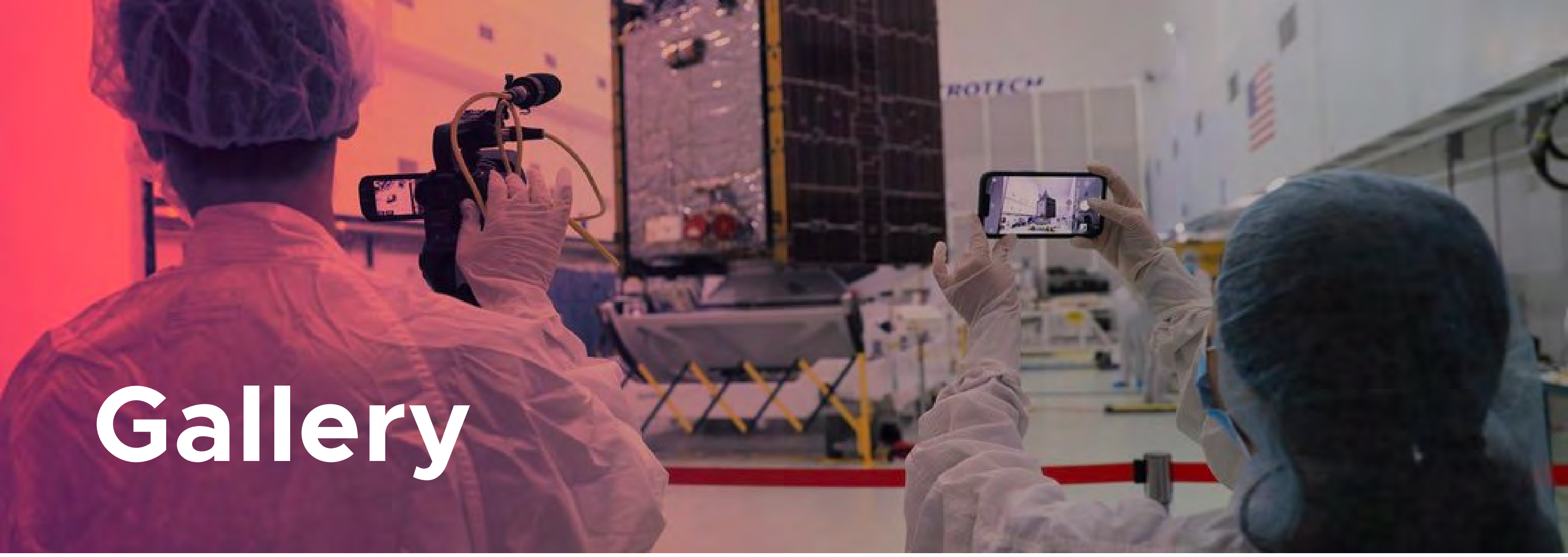
The History and Future of Laser Communications

DSOC is a natural extension of the experiments in laser communications that have come before it. In 2013, NASA's Lunar Laser Communications Demonstration tested record-breaking uplink and downlink data rates between Earth and the Moon. In 2021, NASA's Laser Communications Relay Demonstration launched to test high-bandwidth optical communications from geostationary orbit and to demonstrate relay capabilities so that spacecraft don't need to maintain a direct line of sight with Earth to communicate. In 2022, NASA's TeraByte InfraRed Delivery system downlinked the highest-ever data rate from a satellite in low-Earth orbit to a ground-based receiver.

These demonstrations form the foundations for NASA's operational use of laser communications. The agency's Integrated LCRD Low-Earth Orbit User Modem and Amplifier Terminal (ILLUMA-T) will launch in 2023 to the International Space Station, empowering the astronauts living and working there with new communications capabilities. The Orion Artemis II Optical Communications System will enable high-speed communications during the next human mission to the Moon.

But to test how optical communications may be possible beyond the Moon, new technologies need to be demonstrated. With its launch set for October 2023, DSOC will take optical communications into deep space for the first time. This will set the foundation for establishing higher data-rate returns from future robotic and human missions to Mars and beyond.

For more on DSOC, visit https://www.nasa.gov/mission_pages/tdm/dsoc/.



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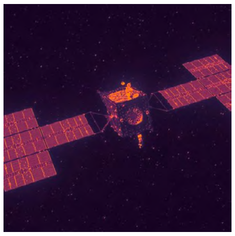

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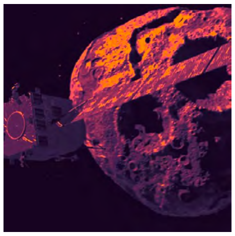

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Psyche Video Playlist

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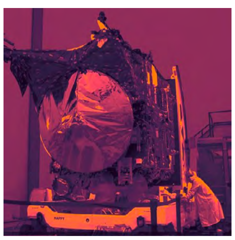
Psyche Mission Media Reel



Psyche in the JPL Clean Room (Media Opportunity) Raw Video

Watch the Video

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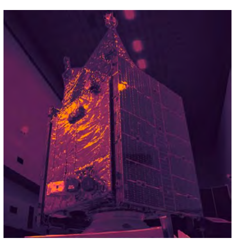

Psyche at Astrotech Space Operations facility (Media Opportunity) Raw Video

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