

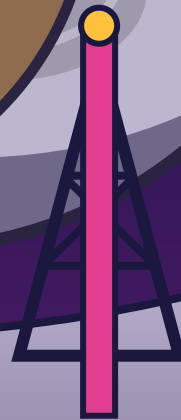
PSYCHE OUTPOST KIT

MINOR PLANET No.

16



Travel to metal-rich asteroid 16 Psyche.
Mine metal. Build your base.



ENGINEERING CREW EDITION

5 build challenges • trip planner • outpost designer • math •
logbook

AGES 8–14
HOME • HOMESCHOOL • CLASSROOM
PRINTABLE PDF

Welcome to the Crew

Your guide to the Psyche Outpost Kit



SAMPLE EDITION

You're on the build crew!

Imagine a future where people travel to **16 Psyche**, metal-rich asteroid. You've been picked for the **first construction crew**. Your jobs: **plan the trip, get there, mine metal, and build an outpost** that keeps everyone safe.

This kit is about **engineering and doing**. You will design, build, test, break, fix, and improve real models made from things around your home.

REAL-WORLD CHECK

No person has ever been to Psyche. NASA's **robotic** Psyche spacecraft launched on Oct. 13, 2023 and is scheduled to reach the asteroid in **summer 2029**. The real facts in this kit come from NASA and JPL (see the Sources page). Crew trips, ships marked "*game numbers*," and outposts are pretend, for practicing engineering.

How to use this kit

- 1 Read the **Crew Briefing** (3 pages) to learn about your destination.
- 2 **Plan your trip**: pick a ship, plot a route, budget fuel.
- 3 Tackle the **5 Engineering Challenges**. Every one ends with an **Improve It** redesign.
- 4 Design your **outpost**, solve the **math sheets**, and fill in your **Crew Logbook**.
- 5 Earn your **Outpost Crew Certificate**!

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CREW MEMBER

Name: _____

Crew role: _____

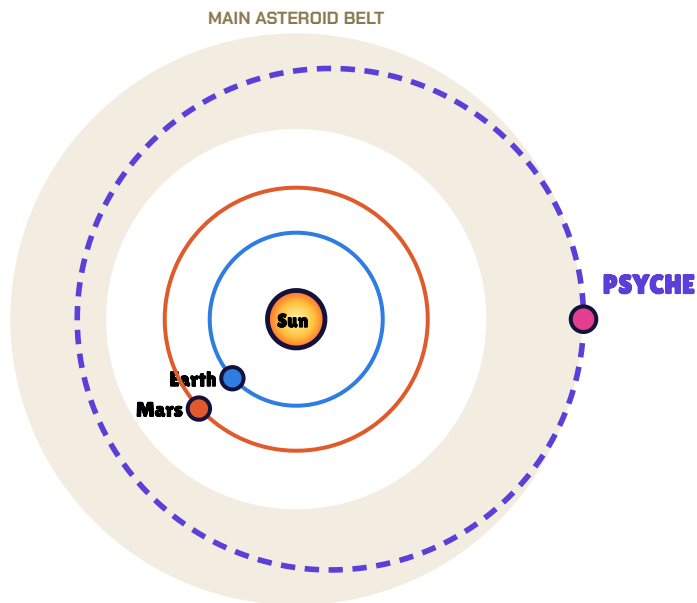
Start date: _____

Sample edition of a printable kit (full kit \$29 at 16psyche.space). Grown-ups: please read the Parent & Teacher Guide and safety notes before building. Not affiliated with or endorsed by NASA, JPL, ESA, JAXA or any space agency.



Where Is Psyche?

Find your destination in the solar system



Top view; orbit sizes roughly to scale, shown flat (real orbits are tilted). Sizes of bodies NOT to scale.

~2.9×

farther from the Sun than Earth is, on average. Psyche's distance from the Sun: 235–309 million miles (2.5–3.3 AU).

143–403

million miles between Earth and Psyche. It changes because the two move at different speeds. The low number is the closest the two orbits ever come.

1 AU

= one "astronomical unit," the distance from Earth to the Sun (about 93 million miles).

≈ 5 years

for Psyche to orbit the Sun once (about 1,828 Earth days). That's one Psyche "year."

4 h 12 min

for Psyche to spin once: a Psyche "day." Sunrise to sunrise in about 4.2 hours!

1852

Discovered: March 17, 1852 — Naples, by Annibale de Gasparis

CREW CHECK

1. Where is Psyche? Write its home region:

2. How many Psyche "days" fit in one Earth day (24 hours)? About _____

3. If you were born on Psyche, how many Psyche years old would you be at age 10 (Earth years)?

4. Circle it on the map: where would you build a fuel stop?

Facts: orbit from the JPL Small-Body Database; other facts from Psyche's published sources (Sources page). Earth–Psyche distances are kit calculations from the orbits.



What Is Psyche Made Of?

Size, metal, density, and gravity you can barely feel

A metal-rich world

Psyche is shaped like a lumpy **potato**. Sliced in half at its equator, it would measure **173 miles (280 km)** across at its widest and **144 miles (232 km)** long. Its surface area is about **64,000 square miles**.

Scientists used to think Psyche was almost all metal. Newer data shows it is likely a **mix of rock and metal**, with metal making up about **30% to 60% of its volume**. It may be part of the **metal core of a planetesimal**, a building block of early planets, that survived violent hit-and-run collisions.

It is **dense**: about **3,400–4,100 kg per cubic meter** (212–256 pounds per cubic foot). Water is 1,000 kg per cubic meter, so Psyche material is roughly 3 to 4 times denser than water.

GRAVITY: VERY, VERY WEAK

NASA says Psyche's surface gravity is **less than Earth's and even less than the Moon's**. On Psyche, **lifting a car would feel like lifting a large dog**.

Using JPL's latest mass for Psyche ($GM = 1.601 \text{ km}^3/\text{s}^2$, Farnocchia et al. 2024) and its 222 km diameter, this kit calculates a surface gravity of about **0.130 m/s²**, compared with Earth's **9.8 m/s²**. That's about **1/75** of Earth's, and that is the number this kit uses. NASA's spacecraft will measure Psyche's gravity much more precisely.

DRAW IT: WHAT DOES PSYCHE'S SURFACE LOOK LIKE?

Nobody knows yet! NASA's 3D model from radar and telescope data shows two crater-like dips. Draw your best guess.

What this means for builders

PSYCHE FACT	ENGINEERING PROBLEM
Gravity $\approx 1/75$ of Earth's	A strong push can send people and tools flying up, so use tethers & anchors .
Rock + metal mix	Need a way to sort metal from rock .
4 h 12 min day	Sunlight comes and goes fast, so store power .
$\sim 3\times$ farther from the Sun	Sunlight is weaker, so solar panels make less power .
No air, harsh space radiation	Habitats need sealed walls and thick shielding .

CREW CHECK

If Psyche's metal is 30% to 60% of its volume, and you dig up 10 buckets of Psyche material, between _____ and _____ buckets' worth could be metal.

Facts: NASA Science "Asteroid Psyche" and NASA's Psyche overview page; JPL Psyche press kit; ASU/UC Berkeley Psyche science page. Gravity: kit calculation from the JPL Small-Body Database mass and diameter.

The Real Trip So Far

What NASA's Psyche spacecraft teaches your crew



Follow the robot pathfinder

Before any crew goes, robots scout the way. NASA's **Psyche** spacecraft is traveling **2.2 billion miles (3.6 billion km)** over **nearly 6 years**. Here is its real trip:

OCT 13, 2023

Launch! NASA's Psyche spacecraft rides a SpaceX Falcon Heavy rocket from Kennedy Space Center, Florida.

2023 – 2026

Line up with Mars Thrusters fire on and off to steer toward the right spot near Mars.

MAY 15, 2026

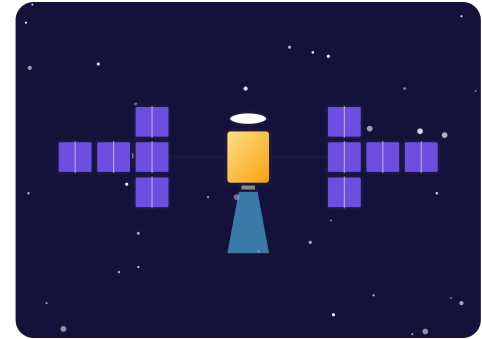
Mars gravity assist Flying close by Mars gives a free speed boost and a slight change of direction, saving propellant.

SEPT 28, 2026

Pedal to the metal Thrusters run nearly all the time (about 90%), pausing about once a week to talk with Earth.

SUMMER 2029

Arrive at Psyche About 2 years in orbit, mapping and studying the asteroid.



Artist-style drawing. Arrays: 81 × 24 ft, almost a tennis court!

How the engine works: solar electric propulsion

4 thrusters

Hall-effect thrusters push out charged atoms (ions) of xenon gas, making a blue glow. Only one runs at a time.

1 AA battery

The thrust (up to about 240–250 millinewtons) feels like holding the weight of one AA battery!

100,000+ mph

Tiny push + years of time = top cruise speed of more than 100,000 mph (relative to Earth).

1,085 kg

of xenon in 7 tanks at launch (2,392 lb). After 3 years, it had used about one third.

21 kW → 2–3 kW

Solar power: 21 kilowatts near Earth, but only 2.3–3.4 kW at the asteroid. Sunlight is weaker far away!

4 tools

Multispectral imager, gamma-ray & neutron spectrometer, magnetometer, and radio gravity science.

ENGINEER'S TAKEAWAY

Why choose a gentle engine that takes years instead of a giant blast?

Facts: NASA Science "Psyche Spacecraft" and "Pedal to the Metal: NASA's Psyche Heads Toward Asteroid Belt" (Oct. 22, 2026); NASA JPL Education "Teachable Moment." NASA lists thrust as up to 240 mN on the spacecraft page and up to 250 mN in the 2026 update.

Choose Your Ship

Fast and thirsty, or slow and efficient?



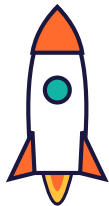
SAMPLE EDITION

GAME NUMBERS

The ships on this page and their numbers are **made up for practice**. They are not real rockets. Every crew leaves Earth on a big booster rocket (NASA's Psyche rode a **Falcon Heavy**). The ship you choose does the rest of the trip. Trip times are based on the shortest simple path to Psyche (about 1.4 years for a quick chemical rocket).

BLAZE-1

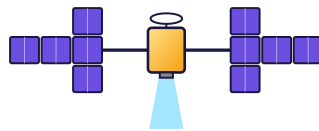
Chemical rocket ship



Push	Huge bursts
Trip time	1.5 years
Fuel use	HIGH
Power	Fuel tanks only
Good for	Speed

ION GLIDER

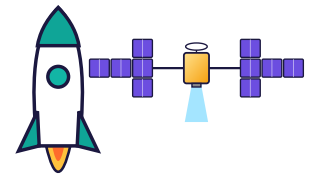
Solar electric ship



Push	Gentle, nonstop
Trip time	3 years
Fuel use	LOW
Power	Giant solar arrays
Good for	Saving fuel

COMBO HAULER

Chemical + electric



Push	Kick, then cruise
Trip time	2.5 years
Fuel use	MEDIUM
Power	Tanks + solar
Good for	Balance

THINK LIKE A TRIP PLANNER

- Which ship works most like NASA's real Psyche spacecraft? _____
- Your crew needs food, air, and water for the whole trip. Which ship needs the **fewest** supplies? Why?

- Which ship might bring the **most metal** home? (Find out on the Fuel Budget page.)

MY CREW'S CHOICE

We choose: _____

Because:

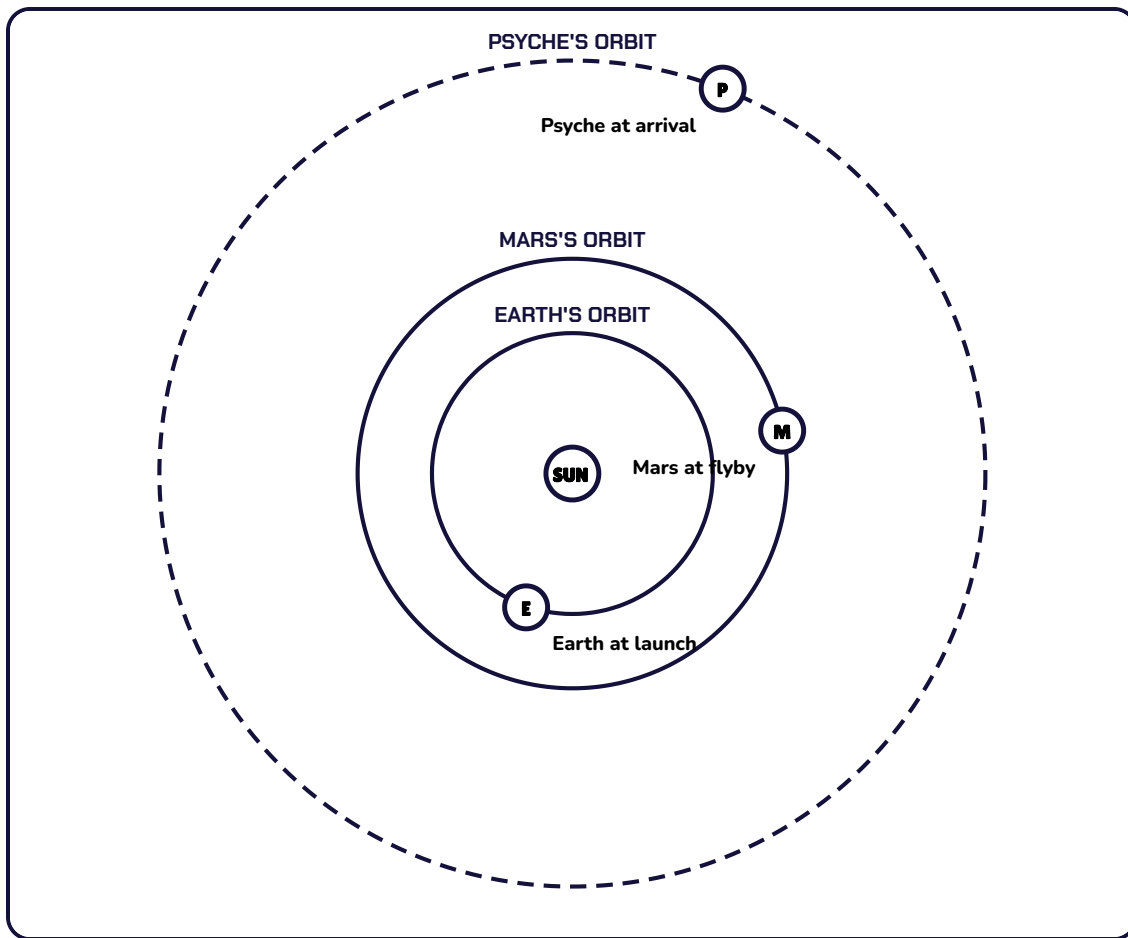
One risk of our choice is:

DESIGN A PATCH FOR YOUR SHIP



Plot Your Route

Draw your path from Earth to Psyche



Trip planner steps

- 1 Find **E**: your launch point on Earth's orbit.
- 2 Ships can't fly in straight lines, because everything is moving around the Sun. Draw a path that **curves** around the Sun, in the same direction the planets go (counterclockwise on this map).
- 3 Pass close by **M** for your Mars gravity-assist boost. Draw a ★ there.
- 4 Keep curving until you meet Psyche at **P**.
- 5 Draw little arrows → where your thrusters fire. Ion Glider crews: arrows almost everywhere!

MEASURE YOUR ROUTE

Lay a piece of string along your path, then measure it.

My route = _____ cm

The real Psyche route is about 2.2 billion miles. On my map, 1 cm stands for about _____ million miles.

Hint: $2,200 \text{ million} \div \text{your cm}$

WHY CAN'T WE FLY STRAIGHT THERE?



Budget Your Fuel

Spend fuel wisely, or you'll run out far from home

GAME RULES (MADE-UP NUMBERS FOR PRACTICE)

Every ship starts with **100 fuel points**. You must arrive with at least **10 points left** as a safety reserve. Each point you have **above** the reserve lets you carry **1 tonne (1,000 kg)** of metal home.

TRIP LEG	BLAZE-1	ION GLIDER	COMBO HAULER
Leave Earth's orbit	30	15	20
Cruise to Mars	20	10	15
Mars gravity assist (free boost: SUBTRACT)	-10	-10	-10
Cruise to Psyche	30	20	25
Brake into orbit at Psyche	20	10	15
Land and hop to the mine site	10	10	10
TOTAL FUEL USED			
FUEL LEFT (100 - total)			
Pass the 10-point reserve? (yes / no)			
Tonnes of metal you can bring home			

CREW DECISION

1 Which ship is fastest **and** still passes the reserve rule?

 ANSWER

2 Which ship brings home the most metal? How many tonnes?

 ANSWER

3 What if you skipped the Mars flyby? Which ships would still pass?

 ANSWER

REAL FUEL CHECK (REAL NASA NUMBERS)

NASA's Psyche launched with about **1,085 kg** of xenon. In its first 3 years it used about **one third**.

4 About how many kg of xenon were used?

 ANSWER

5 About how many kg were left?

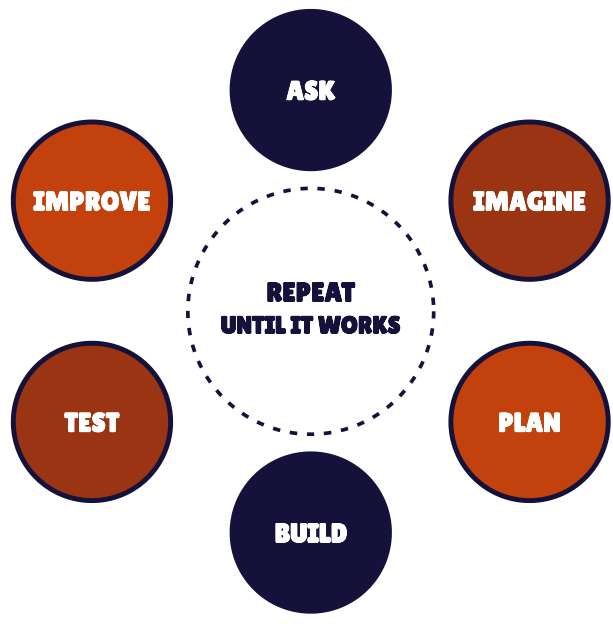
 ANSWER

CREW MEMO: WHICH SHIP DO WE PICK NOW, AND WHY?



How Engineers Build

The design loop you'll use for every challenge



ASK What problem are we solving? What are the rules?

IMAGINE Brainstorm lots of ideas. Wild ones count!

PLAN Sketch one design. List materials.

BUILD Make it. Work safely as a team.

TEST Try it. Measure. Write down results.

IMPROVE Change ONE thing, then test again.

Engineers expect first designs to fail. A failed test is data: it tells you what to fix.

CREW SAFETY CODE

- ☐ A grown-up does all craft-knife cutting and hole-poking.
- ☐ Use child-safe scissors. Cut away from your body.
- ☐ Use only big magnets (fridge or bar magnets). Never put magnets in your mouth.
- ☐ Don't eat any build materials, not even the rice!
- ☐ Never put string, tethers, or bands around anyone's neck.
- ☐ Lamps get hot. Keep paper and hands away from bulbs.
- ☐ Clean up spills (rice, sand, water) so no one slips.

SCORE EVERY BUILD

STARS	MEANS
★	We built it and tested it.
★★	It met the goal at least once.
★★★	We improved it and the retest was better.

Team roles to rotate: **Lead Engineer, Builder, Tester, Data Recorder.**

OUR CREW'S ENGINEERING GOAL THIS WEEK

Core Drill Rig

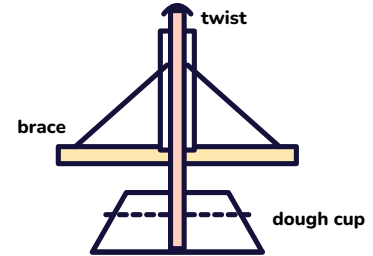
Pull a sample from deep inside Psyche



WHY PSYCHE NEEDS THIS

Before mining, crews must know what is **under** the surface. A core drill pulls out a tube of layers. On Psyche, gravity is so weak (about **1/75** of Earth's) that pushing down on a drill would push **you and the rig up** instead. Your rig must hold itself steady.

ONE WAY TO BUILD IT



MATERIALS

- ☐ 3–4 clear plastic straws (wide smoothie straws work best)
- ☐ 1 paper towel tube
- ☐ Cereal-box cardboard
- ☐ Masking tape
- ☐ 4 craft sticks or unsharpened pencils
- ☐ Play-dough or modeling clay, 3+ colors
- ☐ A small cup or yogurt container
- ☐ A few small pieces of foil ("metal nuggets")
- ☐ Ruler, marker, child-safe scissors

BUILD STEPS

- 1 Make Psyche:** a partner presses 3 colored dough layers into the cup and hides foil nuggets in one layer. Don't peek!
- 2** Cut a 15 cm × 15 cm cardboard base with a hole in the middle the size of the tube.
- 3** Stand the tube in the hole and tape it upright. This is your **drill guide**.
- 4** Tape 3–4 craft sticks from the base up to the tube as **braces** so it can't wobble.
- 5** Mark a straw every 1 cm with a marker. Slide it into the guide.
- 6** Set the rig on top of the cup. **Twist** the straw down slowly. Twist, don't stab.
- 7** Pinch the top of the straw, pull it out, and push the core onto paper with a pencil.

BLUEPRINT: SKETCH AND LABEL YOUR DESIGN BEFORE YOU BUILD

Core Drill Rig

Test it, record it, make it better



Test it

Drill 3 cores in different spots. Lay them side by side and look for layers and metal.

CORE #	DEPTH (CM)	LAYERS / COLORS SEEN	METAL FOUND?	RIG STAYED STRAIGHT?
1				
2				
3				

PREDICT BEFORE YOU TEST

I think our design will _____

Improve it: redesign

REDESIGN CHALLENGE

Hands-off test: on Psyche you can't lean on the drill. Redesign your rig so it stays put while drilling **without anyone holding the base**. Ideas: wider feet, anchors pushed into the dough, clamps, or tape "straps." Then draw Psyche's layers from your cores as a cross-section.

WHAT WENT WRONG (OR COULD BE BETTER)?

THE ONE THING WE'LL CHANGE:

SKETCH VERSION 2

Retest result: _____

SCORE



Magnet Metal Sorter

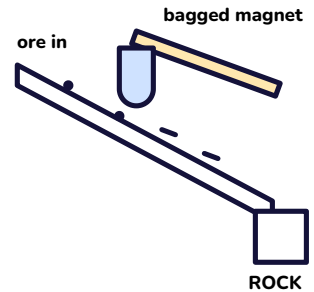
Separate iron-rich metal from rock



WHY PSYCHE NEEDS THIS

Psyche is likely a **mix of rock and metal**. Iron is magnetic, so magnets can pull iron-rich pieces away from rock. But careful: **not all metals are magnetic**. Aluminum foil and most coins are not! Your sorter must grab the magnetic metal and leave everything else behind.

ONE WAY TO BUILD IT



MATERIALS

- ☐ Bowl + 1 cup dry rice or lentils (the "rock")
- ☐ 20 steel paperclips (the "iron")
- ☐ 10 small balls of aluminum foil
- ☐ 10 plastic beads or buttons
- ☐ 1–2 large fridge or bar magnets
- ☐ 1 zip-top sandwich bag
- ☐ Cardboard (about 30 cm long) for a chute
- ☐ Ruler or stick, tape, 2 cups as bins
- ☐ Timer

BUILD STEPS

- 1** Mix the rice, paperclips, foil balls, and beads in the bowl. This is your **ore**.
- 2** Fold up the long sides of the cardboard to make a **chute**. Prop one end on a book.
- 3** Put the magnet **inside the zip bag**. (Pulling the bag off the magnet drops the clips: easy unloading!)
- 4** Tape the bagged magnet to the end of a ruler to make a **sweeper arm**.
- 5** Pour ore slowly down the chute while the sweeper catches metal.
- 6** Unload the metal into the "METAL" cup. Everything else goes in "ROCK."

SAFETY

Use only large magnets. Small, powerful magnets (like magnet balls) are dangerous if swallowed. Keep magnets away from phones, cards, and anyone with a pacemaker. Rice and beads are choking hazards for children under 3.

BLUEPRINT: SKETCH AND LABEL YOUR DESIGN BEFORE YOU BUILD

Magnet Metal Sorter

Test it, record it, make it better



Test it

Run your sorter for **60 seconds**. Count what ended up in the METAL cup. Capture rate = clips caught ÷ 20 × 100.

RUN	CLIPS CAUGHT (OF 20)	CAPTURE RATE %	WRONG ITEMS IN METAL CUP	NOTES
1				
2				
3				

PREDICT BEFORE YOU TEST

I think our design will _____

Improve it: redesign

REDESIGN CHALLENGE

Make it **faster and cleaner**: catch more clips with fewer wrong items. Ideas: a funnel to slow the flow, a second magnet stage, tapping the chute to shake ore loose, or a different chute angle. Change one thing, then retest.

WHAT WENT WRONG (OR COULD BE BETTER)?

THE ONE THING WE'LL CHANGE:

SKETCH VERSION 2

Retest result: _____

SCORE



Shielded Habitat

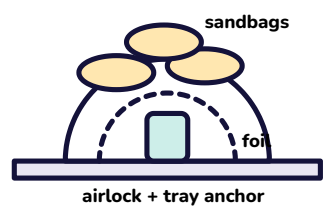
A home that survives low gravity and radiation



WHY PSYCHE NEEDS THIS

Psyche has **no air** and no thick atmosphere to block harsh space radiation, and its 4 h 12 min days mean sunlight and shadow come and go fast. It is cold there: about -110 °C (-170 °F). In low gravity, a habitat must be **anchored** so it can't slide or tip. Crews might pile up loose surface material for extra shielding.

ONE WAY TO BUILD IT



MATERIALS

- ☐ Cardboard (cereal boxes, shoebox)
- ☐ Aluminum foil
- ☐ Tape
- ☐ 2 ice cubes, each in a small zip bag
- ☐ Flashlight
- ☐ Rice or sand in small zip bags ("regolith sandbags")
- ☐ A baking tray (your surface)
- ☐ Paper clips or binder clips
- ☐ Small toy to be the "crew"

BUILD STEPS

- 1** Plan a shape: dome, box, tube, or your own idea. It must fit the crew toy and an ice cube.
- 2** Build the walls from cardboard. Fold strips into arches for a dome.
- 3** Cover the outside with foil, shiny side out.
- 4** Add an **airlock door** flap that closes tightly.
- 5** Stack regolith sandbags on the roof and sides for shielding.
- 6** Anchor the habitat to the tray with tape or clips so it can't move.

SAFETY

Lamps get hot: keep paper and foil away from the bulb. A grown-up handles any cutting with a craft knife.

BLUEPRINT: SKETCH AND LABEL YOUR DESIGN BEFORE YOU BUILD

Shielded Habitat

Test it, record it, make it better



Test it

Run three tests. **Note:** light and heat are only *stand-ins* for space radiation; real radiation shielding must be much thicker. **A. Light leak:** in a dark room, put the flashlight inside and count spots where light escapes. **B. Ice cube:** put one bagged ice cube inside and one outside, under a lamp (at least 30 cm away) or in the sun for 20 min, then compare. **C. Shake:** gently shake the tray 10 times.

TEST	RESULT	PASS?	WHAT WE NOTICED
A. Light leaks (count)			
B. Ice cube: inside vs. outside			
C. Shake test (slid or tipped?)			

PREDICT BEFORE YOU TEST

I think our design will _____

Improve it: redesign

REDESIGN CHALLENGE

Cut your light leaks to **zero** and keep the inside ice cube frozen longer, **without** adding more than 2 extra sandbags. Where is the weak spot: the door, the seams, or the roof?

WHAT WENT WRONG (OR COULD BE BETTER)?

THE ONE THING WE'LL CHANGE:

SKETCH VERSION 2

Retest result: _____

SCORE





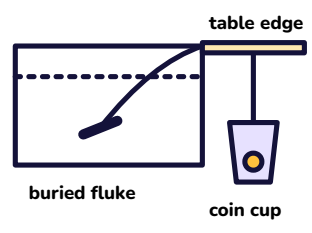
Tether & Anchor System

Keep your crew and gear from floating off

WHY PSYCHE NEEDS THIS

With gravity only about **1/75 of Earth's**, a strong push could send a crew member high above the surface, and they would take a long time to come back down. Tethers connect people and tools to **anchors** dug into the loose surface. Your job: build the anchor that holds the most.

ONE WAY TO BUILD IT



MATERIALS

- ☐ Shoebox or bin filled 10 cm deep with dry rice, sand, or soil
- ☐ 1 meter of string
- ☐ Plastic spoons, craft sticks, pencils
- ☐ Cardboard strips
- ☐ Tape
- ☐ Paper cup with a string handle (the "load bucket")
- ☐ Coins or metal washers
- ☐ Ruler

BUILD STEPS

- 1** Set the box at the table edge. Run the string from the anchor, over the edge, to the paper cup.
- 2 Design A, Stake:** push a pencil straight down and tie the string to the top.
- 3 Design B, Fluke:** tie the string to the middle of a spoon or craft-stick T and bury it **sideways**.
- 4 Design C, Spiral:** wrap a cardboard strip around a pencil to make a screw, then twist it in.
- 5** Bury each anchor to the same depth so the test is fair.
- 6** Add coins to the cup **one at a time** until the anchor pulls out.

SAFETY

Never loop string around anyone's neck or wrist. Pull gently and keep sand or rice inside the box.

BLUEPRINT: SKETCH AND LABEL YOUR DESIGN BEFORE YOU BUILD



Tether & Anchor System

Test it, record it, make it better

Test it

Test each design 3 times. Score = the number of coins in the cup just before the anchor pulled free.

DESIGN	TRY 1	TRY 2	TRY 3	AVERAGE
A. Stake				
B. Fluke				
C. Spiral				
My own design				

PREDICT BEFORE YOU TEST

I think our design will _____

Improve it: redesign

REDESIGN CHALLENGE

Invent a **Design D** that beats your best average. Combine shapes, go wider, add more arms, or link 2 anchors to one tether. Bonus: make a paper-clip "carabiner" that clips the tether on and off quickly.

WHAT WENT WRONG (OR COULD BE BETTER)?

THE ONE THING WE'LL CHANGE:

SKETCH VERSION 2

Retest result: _____

SCORE



Mini Cargo Rover

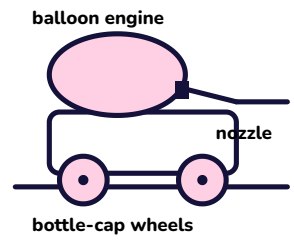
Haul cargo from the mine to the base



WHY PSYCHE NEEDS THIS

Rovers carry ore around the outpost. A radio signal takes about **12 min 45 s to 36 min 4 s** to travel one way between Earth and Psyche, so no one on Earth can steer in real time. In low gravity, wheels press down lightly and get less grip, and bumps can bounce a rover. Design for **traction and stability**.

ONE WAY TO BUILD IT



MATERIALS

- ☐ Small cardboard box, juice box, or plastic bottle (the body)
- ☐ 4 plastic bottle caps (wheels)
- ☐ 2 straws (axle holders) + 1 straw for the nozzle
- ☐ 2 wooden skewers with points cut off by a grown-up, or 2 pencils (axles)
- ☐ 1 balloon (latex-free if anyone is allergic)
- ☐ Rubber bands, tape
- ☐ Washers or coins (cargo)
- ☐ A towel (rough "regolith" track)
- ☐ Tape measure

BUILD STEPS

- 1** A grown-up pokes a hole in the center of each bottle cap.
- 2** Tape 2 straws across the bottom of the body, one at the front and one at the back.
- 3** Slide an axle through each straw. Push a cap onto each end. Check that the wheels spin freely.
- 4** **Balloon engine:** slip the balloon over one end of the nozzle straw and seal it with a rubber band.
- 5** Tape the nozzle on top of the rover, pointing backward.
- 6** Blow up the balloon through the straw, pinch it, set the rover down, and let go!

SAFETY

Don't share balloons or nozzles. A grown-up handles skewers and hole-poking.

BLUEPRINT: SKETCH AND LABEL YOUR DESIGN BEFORE YOU BUILD

Mini Cargo Rover

Test it, record it, make it better



Test it

Test on 2 surfaces, then add cargo. Measure the distance from the start line to where the rover stops.

RUN	SURFACE	CARGO (WASHERS)	DISTANCE (CM)	STAYED STRAIGHT?
1	Smooth floor	0		
2	Towel	0		
3	Smooth floor	5		
4	Towel	5		

PREDICT BEFORE YOU TEST

I think our design will _____

Improve it: redesign

REDESIGN CHALLENGE

Make your rover carry **5 washers across the towel** as far as possible. Ideas: rubber-band treads on the wheels, wider wheels, a lighter body, a longer nozzle, or a cargo bin placed over the axles.

WHAT WENT WRONG (OR COULD BE BETTER)?

THE ONE THING WE'LL CHANGE:

SKETCH VERSION 2

Retest result: _____

SCORE



Design Your Outpost

Lay out power, digging, processing, and habitat on grid paper



SAMPLE EDITION

N ↑

SCALE: 1 SMALL SQUARE = 10 m · 1 BIG SQUARE = 40 m

MAP KEY

- PWR** Power: solar arrays + batteries
- MINE** Mining site + drill rigs
- SMELT** Smelter: melts and separates metal
- HAB** Habitat: where the crew lives
- ROV** Rover garage + charging
- PAD** Landing pad
- STORE** Metal storage + cargo

DESIGN RULES

- ☐ Put the **smelter near the mine** to save rover trips.
- ☐ Keep the **landing pad far from the habitat**. Rocket blasts kick up rock.
- ☐ Draw **power cables** (zig-zag lines) to every building.
- ☐ Sunlight at Psyche is about **9× weaker** than at Earth: draw **extra** solar panels, or a power plant.
- ☐ Draw **rover roads** (dashed lines).
- ☐ Mark **anchor points** with ⚓.

CHECK YOUR PLAN

Longest rover road: _____ m

Habitat to pad: _____ m

Outpost name: _____



Jump Height on Psyche

How high can you leap when gravity is $\sim 1/75$ of Earth's?

THE RULE FOR THIS PAGE

Psyche's gravity is about **$1/75$** of Earth's (kit calculation from its mass and size). If you push off just as hard, your jump goes about **75 times higher** and keeps you in the air about **75 times longer**. On the Moon, gravity is **$1/6$** of Earth's (NASA), so a jump goes about **6 times higher**.

- 1** A crew member jumps **30 cm** high on Earth. How high would the same jump go on Psyche? Give your answer in cm and in meters.

ANSWER

- 2** That Earth jump keeps them in the air for about **0.5 seconds**. About how long would they be in the air on Psyche?

ANSWER

- 3** How high would the 30 cm jump go on the **Moon**? About how many times higher is the Psyche jump than the Moon jump?

ANSWER

- 4** A car weighs about **4,000 pounds** on Earth. About how much would it feel like it weighs on Psyche?

ANSWER

YOUR TURN: MEASURE YOUR JUMP

With a grown-up, stand next to a wall outdoors or on a soft surface. Reach up and mark the wall with chalk or a sticky note. Then jump and tap the wall as high as you can. Jump height = jump mark – reach mark.

	MY JUMP ON EARTH (CM)	$\times 6 =$ ON THE MOON (CM)	$\times 75 =$ ON PSYCHE (CM)	PSYCHE JUMP IN METERS
Try 1				
Try 2				

- 5 Engineer's question:** A 22-meter jump sounds fun, but why could it be dangerous at an outpost? Name one thing you'd build to fix it.

ANSWER



Travel Time & Signal Delay

Big distances, long trips, slow messages

2.2 billion mi

Real trip length of NASA's
Psyche spacecraft

186,000 mi/s

About how fast radio signals
(light) travel

**140 million mi -
400 million mi**

Closest and farthest distance
between Earth and Psyche
(rounded)

1 A fast chemical rocket on the shortest route takes about **1.4 years** to reach Psyche. How many months is that?

ANSWER

2 The route is about 2.2 billion mi in about 1.4 years. About how many miles is that **per year**? About how many **per day**? (Use 365 days per year.)

ANSWER

3 Signal delay: When Psyche is closest (140 million mi away), how many seconds does a radio message take to arrive?

ANSWER

4 When Psyche is farthest (400 million mi), how long does a message take one way? If you ask a question, how long until you hear an answer (round trip)?

ANSWER

5 A Psyche day is about 4 h 12 min. How many minutes is that? About how many Psyche days fit in one Earth day (1,440 minutes)?

ANSWER

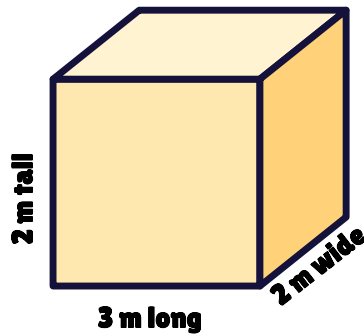
6 Game ships: How many more years does the Ion Glider (3 years) take than the Blaze-1 (1.5 years)? Would you trade that time for the extra cargo? Why?

ANSWER



Fill Your Cargo Hold

How much Psyche metal can your ship carry?



FACTS YOU NEED

Volume of a box = length $\times$ width $\times$ height.

NASA estimates Psyche material has a density of **3,400–4,100 kg per cubic meter**. For this page, use **4,000 kg per m³** (a round number inside NASA's range).

Metal may be **30% to 60%** of Psyche's volume (NASA).
Psyche's gravity $\approx$ **1/75** of Earth's.

- 1** What is the volume of the cargo hold (3 m $\times$ 2 m $\times$ 2 m)?

ANSWER

- 2** If you fill it with Psyche material at 4,000 kg per m³, what is the **mass** of the load?

ANSWER

- 3** If the material is **30% metal**, how many m³ of metal are in the hold? What if it's **60%**?

ANSWER

- 4** On Psyche, about how heavy would the full load **feel** (compared to lifting kilograms on Earth)?
Hint: divide by 75.

ANSWER

- 5 Tricky!** The load feels light on Psyche. Is it just as hard to **start and stop** it moving as on Earth? Explain. (Hint: mass doesn't change, only weight does.)

ANSWER

DESIGN YOUR OWN CARGO HOLD

MY HOLD	LENGTH (M)	WIDTH (M)	HEIGHT (M)	VOLUME (M ³)	MASS AT 4,000 KG/M ³
Design 1					
Design 2					



Crew Logbook: Days 1-3

Engineers write everything down

DAY 1 Briefing & trip plan

Date: _____

Prompt: Which ship did your crew choose and why? What surprised you most about Psyche?

Today's win: _____

Problem we hit: _____

DAY 2 Drill rig & magnet sorter

Date: _____

Prompt: What did your cores show was inside Psyche? What was your sorter's best capture rate, and which change helped most?

Today's win: _____

Problem we hit: _____

DAY 3 Habitat & tethers

Date: _____

Prompt: Where did your habitat leak? Which anchor design held the most coins, and why do you think its shape worked?

Today's win: _____

Problem we hit: _____



Finish strong and look back

Date:

Today's win:

Problem we hit:

Date:

[illegible]

Today's win:

Problem we hit:

DRAW YOUR OUTPOST CREW PATCH

Jobs at the Outpost

Future space careers, and what to learn now to get there



Asteroid Miner

At the outpost: Finds, digs, and processes metal and rock far from Earth.

What to learn: Geology (rocks and minerals), chemistry, math (volume and mass), safety planning

Real today: Mining engineers and geologists do this kind of work on Earth.

Practice in this kit: Challenges 1 & 2, Math Sheet 3



Robotics Engineer

At the outpost: Designs drills, arms, and robots that work on their own when messages take 12 min 45 s to 36 min 4 s to arrive.

What to learn: Coding, electronics, physics, math, building and fixing things

Real today: Robotics engineers build spacecraft and rovers at space agencies and companies.

Practice in this kit: Challenge 5, Math Sheet 2



Habitat Builder

At the outpost: Designs shelters that protect people from radiation, airlessness, cold, and low gravity.

What to learn: Architecture, materials science, physics, human health and needs

Real today: Architects and aerospace engineers are working on space habitat designs.

Practice in this kit: Challenges 3 & 4, Outpost Designer



Rover Driver

At the outpost: Plans safe routes and sends driving commands across rough, low-gravity ground.

What to learn: Maps and geometry, coding, careful planning, teamwork

Real today: NASA rover drivers plan routes for rovers on Mars.

Practice in this kit: Plot Your Route, Challenge 5

WHICH JOB FITS YOU?

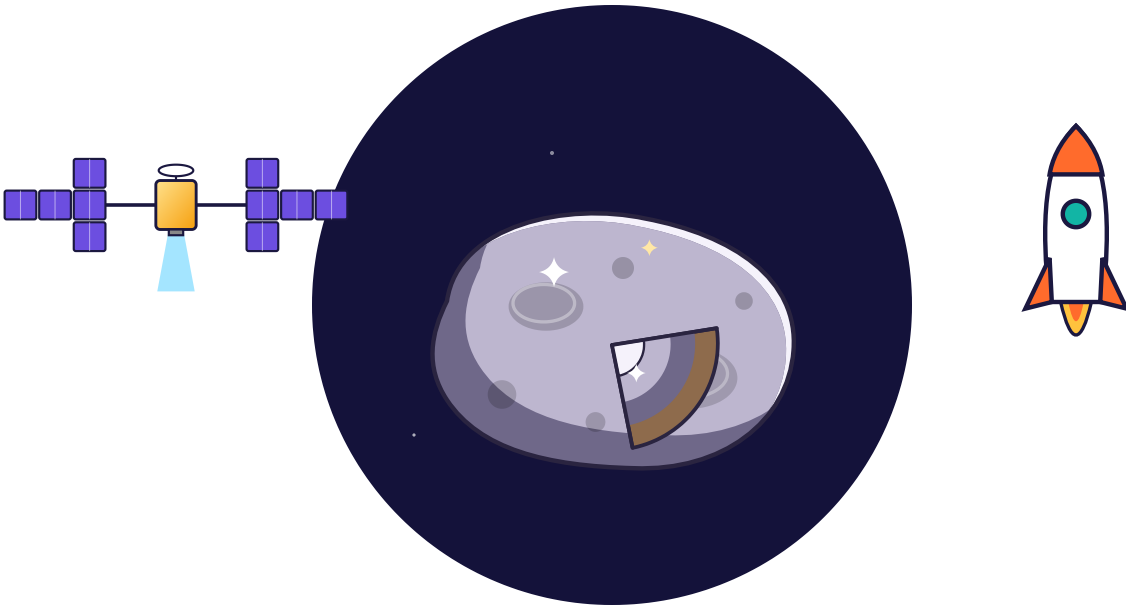
The outpost job I'd want most is _____

because _____

One thing I can start learning this year: _____

Every crew needs: clear writing, teamwork, patience, and the courage to test, fail, and try again.

OUTPOST KITS · 16PSYCHE.SPACE



OUTPOST CREW CERTIFICATE

This certifies that

planned the trip, budgeted the fuel, built and improved a core drill rig, a magnet metal sorter, a shielded habitat, a tether and anchor system, and a mini cargo rover, and designed a working outpost on metal-rich asteroid **16 Psyche**.

Crew role: _____

Outpost Commander (grown-up)

Date

Parent & Teacher Guide

Objectives, schedule, and safety



SAMPLE EDITION

Learning objectives

- ☐ Use the engineering design process: define a problem, then build, test, and **improve** a design based on data.
- ☐ Explain what and where 16 Psyche is, what it may be made of, and why its weak gravity matters.
- ☐ Compare trade-offs (speed vs. fuel vs. cargo) when making a plan.
- ☐ Practice ratios, multiplying and dividing big numbers, volume, percent, and unit conversion.
- ☐ Tell **measured** facts from **estimates** and **guesses**.
- ☐ Record data, explain results in writing, and work as a team.

Standards connections: NGSS Engineering Design (3-5-ETS1 and MS-ETS1: define problems, compare solutions, test and improve); upper-elementary and middle-school number, ratio, and volume skills.

Adapting by age

Ages 8–10: do one challenge per day, allow calculators on Math Sheet 2, and let a grown-up be the Data Recorder. **Ages 11–14:** require a written prediction before every test, and change only one variable per redesign.

Classroom tips

Teams of 3–4 rotate roles (Lead Engineer, Builder, Tester, Data Recorder). Gallery-walk the outpost designs on Day 5. Each family or team needs its own set of materials.

Real vs. pretend

Facts about Psyche are real and sourced; numbers worked out by the kit (gravity, distances, trip lengths, signal delays) are labeled "kit calculation." Crew travel, the three ships, fuel points, and tonnes are **game numbers**, labeled on each page.

5-day schedule (about 60–90 min per day)

DAY	FOCUS	PAGES
1	Crew Briefing, choose ship, plot route, fuel budget, design loop	2–9
2	Challenge 1 Drill Rig + Challenge 2 Magnet Metal Sorter; Math Sheet 1	10–13, 21
3	Challenge 3 Habitat + Challenge 4 Tether & Anchor	14–17
4	Challenge 5 Mini Cargo Rover; Math Sheets 2–3	18–19, 22–23
5	Outpost Designer, Future Jobs, logbook review, certificate	20, 24–27

SAFETY NOTES FOR GROWN-UPS

- **Cutting:** adults do all craft-knife cutting, hole-poking, and trimming of skewer points.
- **Magnets:** use large fridge or bar magnets only. Small high-power magnets can cause serious internal injury if swallowed. Keep away from pacemakers and electronics.
- **Small parts:** rice, beads, coins, bottle caps, and balloons are choking hazards. Keep them away from children under 3.
- **Balloons:** use latex-free balloons if anyone has a latex allergy. No shared nozzles.
- **Heat:** keep lamps at least 30 cm from builds, and never leave a lamp unattended.
- **String:** never around necks or wrists.
- **Jump test:** outdoors or on a soft surface, with clear space and supervision.

Answer Key

Worked answers for grown-ups



SAMPLE EDITION

Crew Briefing 01

1. Main asteroid belt. 2. About 5.7 ($24 \div 4.20$ h). 3. About 2 ($10 \div 5$).

Crew Briefing 02

Between 3 and 6 buckets.

Choose Your Ship

1. Ion Glider. 2. Blaze-1 (1.5 years): fewest days of food, air and water. 3. See the Fuel Budget answers.

Fuel Budget

	BLAZE-1	ION	COMBO
Total used	100	55	75
Fuel left	0	45	25
Pass reserve?	No	Yes	Yes
Tonnes home	0	35	15

Q1 Combo Hauler. Q2 Ion Glider, 35 tonnes. Q3 Without the flyby, each total is 10 higher (110, 65, 85); Ion Glider and Combo Hauler still pass. Q4 About 362 kg ($1,085 \div 3 \approx 361.7$). Q5 About 723 kg.

Plot Your Route

Divide 2,200 by your string length in cm. We can't fly straight because Earth, Mars and Psyche are all moving; the ship must curve to meet them.

Briefing 03

Example: it uses far less propellant, so a smaller ship can carry more science gear.

Math Sheet 1

1. $30 \times 75 = 2,250$ cm = 22.5 m. 2. $0.5 \times 75 = 37.5$ seconds. 3. Moon: $30 \times 6 = 180$ cm; $2,250 \div 180 \approx 12$. 4. $4,000 \div 75 \approx 53$ pounds. 5. Example: you could crash into equipment, land hard, or drift away from the base, so build tethers, handrails, and anchors.

Math Sheet 2: Travel

1. $1.4 \times 12 \approx 17$ months. 2. ≈ 1.6 billion mi per year; $\approx 4,300,000$ miles per day. 3. $140,000,000 \div 186,000 \approx 12$ min 33 s. 4. ≈ 35 min 51 s one way; round trip ≈ 71 min 41 s. 5. About 252 minutes; $1,440 \div 252 \approx 5.7$. 6. 1.5 years; answers vary.

Math Sheet 3: Cargo

1. 12 m^3 . 2. $12 \times 4,000 = 48,000$ kg. 3. 30%: 3.6 m^3 ; 60%: 7.2 m^3 . 4. $48,000 \div 75 \approx 640$ kg. 5. Yes. The mass stays 48,000 kg, so it takes the same push to start or stop it as on Earth. Only its weight is less.

Challenges

Results vary. Look for fair tests (one change at a time), recorded data, and a redesign explained by evidence. Expected patterns: sideways (fluke) anchors usually hold more than straight stakes; foil and beads should **not** stick to the magnet; wider or treaded wheels usually help on the towel.



Sources & Fact Notes

Where every real number came from

Facts about Psyche in this kit were checked against the sources below on Oct. 23, 2026. Numbers marked **"game numbers"** (ships, fuel points, tonnes) are invented for practice. Numbers marked **"kit calculation"** (gravity, escape speed, Earth distances, trip length, signal delay, temperature) were worked out from the measured size, mass and orbit using standard physics. Where a number is a guess borrowed from similar bodies, the kit says so.

1. **NASA Science, "Asteroid Psyche."** Size, surface area, 30–60% metal, distance from the Sun, orbit of about 5 years, rotation of just over 4 hours, discovery in 1852, main science phase beginning August 2029.
science.nasa.gov/solar-system/asteroids/16-psyche/
2. **NASA Science, Psyche overview page.** Earth–Psyche distance, density of 3,400–4,100 kg/m³, gravity less than the Moon's, the "car feels like a large dog" comparison.
science.nasa.gov (search: Psyche overview)
3. **NASA Science, Psyche spacecraft home page.** Launch on Oct. 13, 2023; about two years orbiting the asteroid; spacecraft almost covers a tennis court.
science.nasa.gov (search: Psyche)
4. **NASA Science, "Psyche Spacecraft."** Solar arrays 81 × 24 ft; 21 kW near Earth and 2.3–3.4 kW at the asteroid; four Hall-effect xenon thrusters; up to 240 mN (one AA battery); seven xenon tanks (2,392 lb / 1,085 kg); instruments.
science.nasa.gov (search: Psyche Spacecraft)
5. **NASA Science blog, "Pedal to the Metal: NASA's Psyche Heads Toward Asteroid Belt" (Oct. 22, 2026).** Near-continuous thrusting since Sept. 28 (about 90% of the time); up to 250 mN; top speed above 100,000 mph; about one third of the xenon used; arrival in summer 2029.
science.nasa.gov/blogs/psyche/2026/10/22/pedal-to-the-metal-nasas-psyche-heads-toward-asteroid-belt/
6. **NASA JPL Education, Teachable Moment on the Psyche asteroid trip.** 2.2 billion miles (3.6 billion km) over nearly 6 years; Mars gravity assist; xenon propellant.
jpl.nasa.gov/edu (search: Explore Mysteries of Earth's Core)
7. **NASA JPL Psyche Press Kit, "Science."** Size, density, gravity, gravity science.
jpl.nasa.gov/press-kits/psyche/
8. **Psyche science team (ASU / UC Berkeley), "Science."** Day of about 4 h 12 min; year of about 1,828 Earth days; average distance of 3 AU.
psyche.ssl.berkeley.edu/science/
9. **NASA Science, "Moon Facts."** The Moon's surface gravity is one-sixth of Earth's.
science.nasa.gov/moon/facts/
10. **Mars flyby date (May 15, 2026):** reported in news coverage of NASA's Oct. 22, 2026 update. NASA confirms the successful Mars gravity assist in source 5.
11. **JPL Small-Body Database, "16 Psyche."** Orbit, 222 km diameter, and mass ($GM = 1.601 \text{ km}^3/\text{s}^2$, Farnocchia et al. 2024). The kit's gravity (about 1/75 of Earth's), escape speed, Earth distances and signal delays are kit calculations from these values.
ssd.jpl.nasa.gov/tools/sbdb_lookup.html#/?sstr=16
12. **Speed of light and radio, about 186,000 miles per second:** a standard physical constant, rounded.

About this kit. Psyche Outpost Kit, Sample edition, by Outpost Kits (10timesIt LLC) · 16psyche.space. Printable for home, homeschool, or one classroom. Illustrations are original artwork, artistic and not to scale. Fonts: Nunito, Lilita One and Chakra Petch (SIL Open Font License). This product is not affiliated with, sponsored by, or endorsed by NASA, JPL, ESA, JAXA or any space agency or university. The future crew travel in this kit is imaginary.