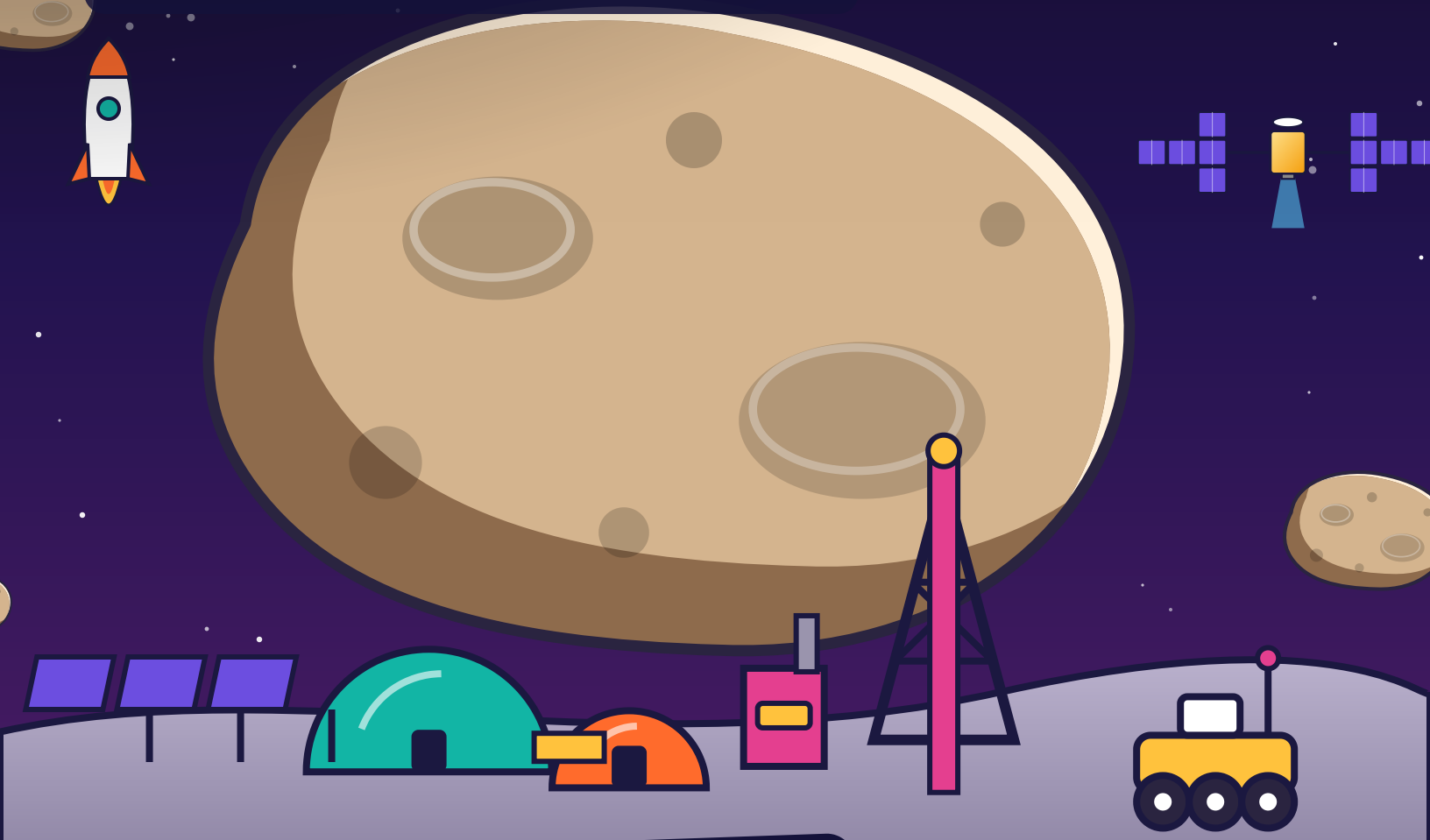
SAMPLE EDITION

GEOGRAPHOS OUTPOST KIT

MINOR PLANET No.
1620

Travel to near-Earth asteroid (Apollo, S-type) 1620 Geographos. 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 ABOARD

Welcome to the Crew

Your guide to the Geographos Outpost Kit

SAMPLE EDITION

You're on the build crew!

Imagine a future where people travel to **1620 Geographos**, near-Earth asteroid (Apollo, S-type). 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 Geographos. No spacecraft has visited Geographos up close yet; what we know comes from telescopes. The real facts in this kit come from published sources (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: _____

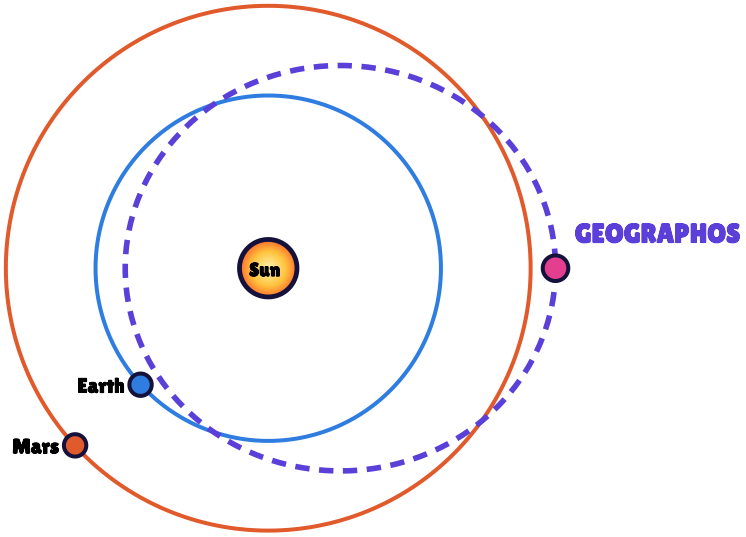
Sample edition of a printable kit (full kit $29 at geographos.space). Grown-ups: please read the Parent & Teacher Guide and safety notes before building. Not affiliated with or endorsed by NASA, JPL, ESA, JAXA or any space agency.

CREW BRIEFING 01

Where Is Geographos?

Find your destination in the solar system

SAMPLE EDITION



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

~1.2×

farther from the Sun than Earth is, on average. Geographos's distance from the Sun: 77–155 million miles (0.8–1.7 AU).

2.75–249

million miles between Earth and Geographos. 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).

≈ 1.4 years

for Geographos to orbit the Sun once (about 508 Earth days). That's one Geographos "year."

5 h 13 min

for Geographos to spin once: a Geographos "day." Sunrise to sunrise in about 5.2 hours!

1951

Discovered: Sept. 14, 1951 by A. G. Wilson and R. Minkowski, Palomar Observatory

CREW CHECK

1. Where is Geographos? Write its home region: _____

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

3. If you were born on Geographos, how many Geographos 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 Geographos's published sources (Sources page). Earth–Geographos distances are kit calculations from the orbits.

CREW BRIEFING 02

What Is Geographos Made Of?

Size, stuff, density, and gravity

SAMPLE EDITION

A stony world

Geographos is about **2.56 km (1.6 miles)** across (5.0 × 2.0 × 2.1 km radar shape). Asteroids like this are called **S-type** (stony). They are made mostly of rocky minerals such as olivine and pyroxene, with some **iron-nickel metal** mixed in, like many meteorites that fall to Earth.

What scientists have found

- [ ] No spacecraft has measured what Geographos is made of. Scientists rely on its colour and brightness through telescopes.

Its density is about **2,700 kg per cubic meter** (assumed (a guess)). Water is 1,000 kg per cubic meter, so Geographos material is about 2.7× as dense as water. Nobody has measured it; this number is borrowed from similar bodies.

GRAVITY: ALMOST ZERO

Geographos's gravity is **tiny**: about **1/10,000** of Earth's. A gentle jump could launch you off into space, because the **escape speed** is only about **160 cm per second** (3.5 mph).

Kit calculation: g = 0.00097 m/s² from mass (assumed density) and diameter. Earth's is 9.8 m/s².

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

No close-up pictures exist yet! Draw your best guess.

What this means for builders

GEOGRAPHOS FACT	ENGINEERING PROBLEM
Gravity ≈ 1/10,000 of Earth's	Push too hard and you float away, so use **tethers & anchors**.
Rock with metal grains	Need a way to **pull metal out of crushed rock**.
5 h 13 min day	Sunlight comes and goes, so **store power**.
About -31 °C (-24 °F)	Habitats need **heaters and insulation**.
No air, harsh space radiation	Habitats need **sealed walls and thick shielding**.

CREW CHECK

Suppose 5% to 10% of the material you dig on Geographos is useful metal (a practice number, not a measurement). If you dig up 10 buckets, between _____ and _____ buckets could be metal.

Facts: Geographos's published sources (see the Sources page). Size: sbdb; density: assumed (a guess) (assumed; a round value typical of S-complex asteroids (Carry 2012)). Gravity, weight and escape speed are kit calculations.

CREW BRIEFING 03

How Do We Know?

Clues, measurements, and mysteries about Geographos

SAMPLE EDITION

Timeline: how we found out

1951 **Discovered:** Sept. 14, 1951 by A. G. Wilson and R. Minkowski, Palomar Observatory

1994 **Closest recent pass:** 5.0 million km in 1994 — not bettered until 2586

From the records

- [ ] Geographos was discovered on 14 September 1951 by Albert George Wilson and Rudolph Minkowski at Palomar Observatory.
- [ ] Its brightness changes by one to two full magnitudes as it rotates, a sign of extreme elongation.
- [ ] Radar images from Goldstone during its 1994 approach showed it to be the most elongated object in the Solar System known at the time.

EVIDENCE BOARD

FACT	VALUE	HOW SURE?
Size	2.56 km	MEASURED
Density	2.7 g/cm³	GUESS
Mass	2.4e+13 kg	GUESS
Spin (day length)	5 h 13 min	MEASURED
Orbit	tracked by JPL	MEASURED
Temperature	≈ -31 °C	ESTIMATED

MEASURED = seen directly. **ESTIMATED** = worked out from other data. **GUESS** = borrowed from similar bodies.

STILL A MYSTERY

- [ ] Nobody knows its density (so its mass is a guess too).
- [ ] Nobody knows what its surface looks like up close.
- [ ] Nobody knows exactly what is under the surface.

MY QUESTIONS FOR THE NEXT SPACECRAFT TO VISIT GEOGRAPHOS

ENGINEER'S TAKEAWAY

Pick one mystery above. What tool would your crew bring to solve it?

Why do engineers design for the **worst case** when a number is only a guess?

Facts: Geographos's published sources (Sources page). "How sure?" stamps are the kit's own labels for each number.

PLAN YOUR TRIP 01

Choose Your Ship

Fast and thirsty, or slow and efficient?

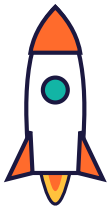
SAMPLE EDITION

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 (like the real robot explorers). The ship you choose does the rest of the trip. Trip times are based on the shortest simple path to Geographos (about 0.6 years for a quick chemical rocket).

BLAZE-1

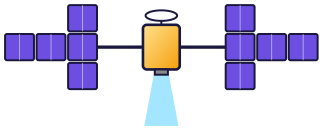
Chemical rocket ship



Push	Huge bursts
Trip time	1 year
Fuel use	HIGH
Power	Fuel tanks only
Good for	Speed

ION GLIDER

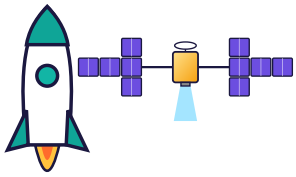
Solar electric ship



Push	Gentle, nonstop
Trip time	2 years
Fuel use	LOW
Power	Giant solar arrays
Good for	Saving fuel

COMBO HAULER

Chemical + electric



Push	Kick, then cruise
Trip time	1.5 years
Fuel use	MEDIUM
Power	Tanks + solar
Good for	Balance

THINK LIKE A TRIP PLANNER

1. Which ship works most like real robot spacecraft that use ion engines (like NASA's Dawn and Psyche)? _____

2. Your crew needs food, air, and water for the whole trip. Which ship needs the **fewest** supplies? Why?

3. 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:

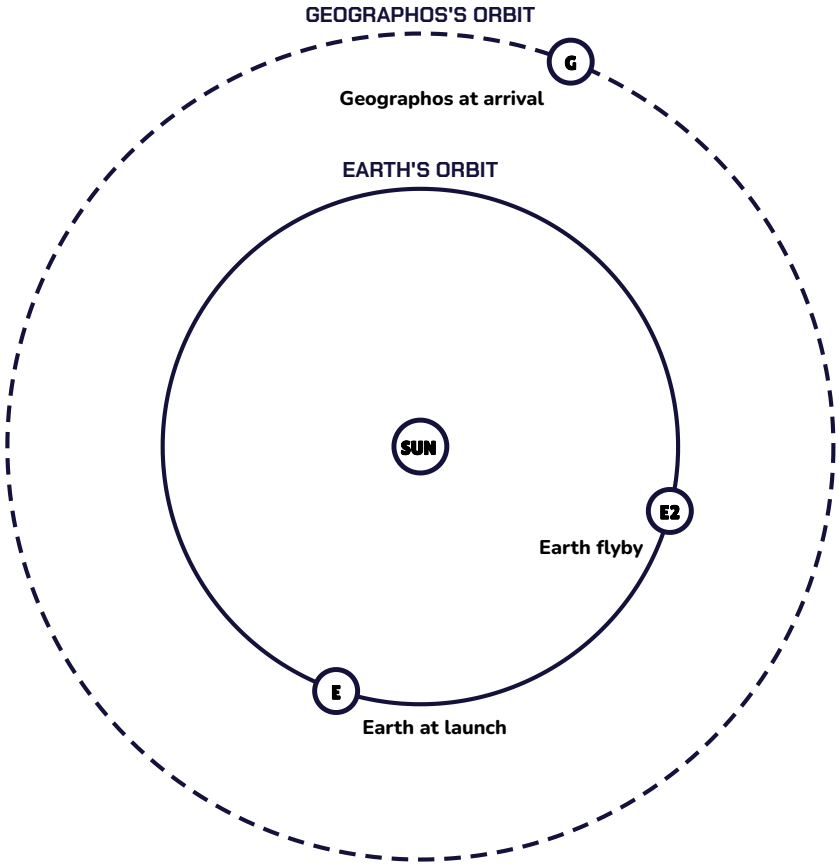
DESIGN A PATCH FOR YOUR SHIP

PLAN YOUR TRIP 02

Plot Your Route

Draw your path from Earth to Geographos

SAMPLE EDITION



Geographos's real orbit stays close to Earth's; it is drawn bigger here so you can see it.

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 **E2** for your Earth gravity-assist boost. Draw a ★ there.
4. Keep curving until you meet Geographos at **G**.
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 shortest simple route to Geographos is about 327 million miles (kit calculation; real routes are often longer). On my map, 1 cm stands for about _____ million miles.

Hint: 327 million ÷ your cm

WHY CAN'T WE FLY STRAIGHT THERE?

PLAN YOUR TRIP 03

Budget Your Fuel

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

SAMPLE EDITION

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	28	14	19
Loop around the Sun	19	9	14
Earth gravity assist (free boost: SUBTRACT)	−10	−10	−10
Cruise to Geographos	28	19	24
Brake to match Geographos's speed	19	9	14
Match speed and touch down gently	2	2	2
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 Earth flyby? Which ships would still pass?

ANSWER

ROCKET-SCIENCE CHECK (KIT CALCULATION)

Engineers measure a trip by the total **change in speed** it needs, called **delta-v**. A simple trip from low Earth orbit to Geographos needs about **9.5 km/s** (no gravity assists).

4 How many meters per second is 9.5 km/s? (1 km = 1,000 m)

ANSWER

5 A car on the highway goes about 30 m/s. How many times faster is that change in speed?

ANSWER

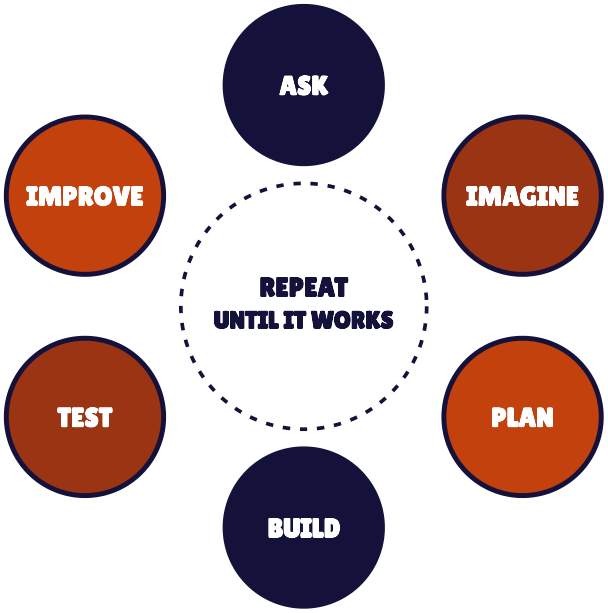
CREW MEMO: WHICH SHIP DO WE PICK NOW, AND WHY?

ENGINEERING CREW

How Engineers Build

The design loop you'll use for every challenge

SAMPLE EDITION



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

CHALLENGE 1 · BUILD

Core Drill Rig

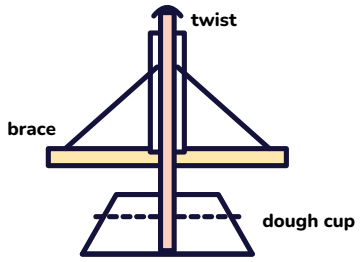
Pull a sample from deep inside Geographos

SAMPLE EDITION

WHY GEOGRAPHOS NEEDS THIS

Before mining, crews must know what is **under** the surface. A core drill pulls out a tube of layers. On Geographos, gravity is so weak (about **1/10,000** 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 Geographos:** 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

CHALLENGE 1 · TEST + IMPROVE

Core Drill Rig

Test it, record it, make it better

SAMPLE EDITION

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 Geographos 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 Geographos'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

CHALLENGE 2 · BUILD

Magnet Metal Sorter

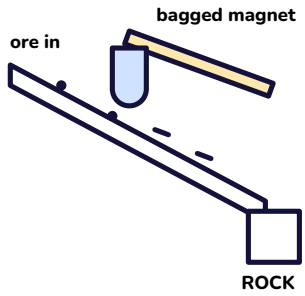
Separate iron-rich metal from rock

SAMPLE EDITION

WHY GEOGRAPHOS NEEDS THIS

Geographos is stony rock with **grains of iron-nickel metal** mixed in, like many meteorites. 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

CHALLENGE 2 · TEST + IMPROVE

Magnet Metal Sorter

Test it, record it, make it better

SAMPLE EDITION

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

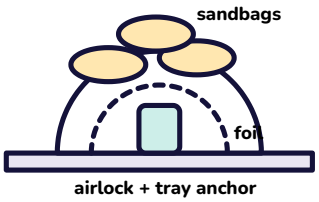
A home that survives low gravity and radiation

SAMPLE EDITION

WHY GEOGRAPHOS NEEDS THIS

Geographos has **no air** and no thick atmosphere to block harsh space radiation, and its 5 h 13 min days mean sunlight and shadow come and go fast. It is cold there: about -31 °C (-24 °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

SAMPLE EDITION

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

CHALLENGE 4 · BUILD

Tether & Anchor System

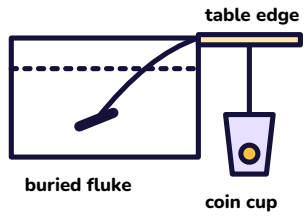
Keep your crew and gear from floating off

SAMPLE EDITION

WHY GEOGRAPHOS NEEDS THIS

With gravity only about **1/10,000 of Earth's**, a gentle push faster than about **160 cm/s** could send a crew member off into space forever. 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

CHALLENGE 4 · TEST + IMPROVE

Tether & Anchor System

Test it, record it, make it better

SAMPLE EDITION

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

CHALLENGE 5 · BUILD

Hopper Bot

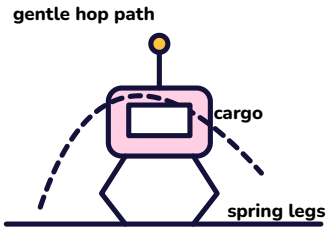
Move cargo where wheels can't grip

SAMPLE EDITION

WHY GEOGRAPHOS NEEDS THIS

On Geographos, gravity is so tiny (about 1/10,000 of Earth's) that a wheel barely presses on the ground, so wheels just spin. Real explorers here use **hoppers** that push off gently, like the Japanese MINERVA-II rovers on asteroid Ryugu. Radio takes about **15 seconds to 22 min 18 s** one way, so a hopper must work on its own. Too hard a hop and it is lost in space!

ONE WAY TO BUILD IT



MATERIALS

- [ ] Small cardboard box or paper cup (the body)
- [ ] 2–4 rubber bands
- [ ] Craft sticks
- [ ] Tape
- [ ] Washers or coins (cargo)
- [ ] A towel or tray with rice (landing zone)
- [ ] Tape measure
- [ ] Masking-tape target ring

BUILD STEPS

1. Tape 2 craft sticks into a **V-shaped spring leg**: hold them together at one end with a rubber band.
2. Make 2–4 spring legs and tape them under the body.
3. Put 2 washers inside as cargo. Tape the lid closed.
4. Make a target ring with masking tape 50 cm away.
5. Press the hopper down gently and let go so it hops toward the ring.
6. Mark where it lands. Did it stay in the landing zone?

SAFETY

Keep faces away from snapping rubber bands. Hop only on the floor or a table, away from people.

BLUEPRINT: SKETCH AND LABEL YOUR DESIGN BEFORE YOU BUILD

CHALLENGE 5 · TEST + IMPROVE

Hopper Bot

Test it, record it, make it better

SAMPLE EDITION

Test it

Do 5 hops. Measure how far each hop goes and whether the cargo stays inside. The goal is **controlled** hops, not the biggest ones.

HOP	PUSH (SOFT/MED/HARD)	DISTANCE (CM)	LANDED IN RING?	CARGO SAFE?
1				
2				
3				
4				
5				

PREDICT BEFORE YOU TEST

I think our design will _____

Improve it: redesign

REDESIGN CHALLENGE

Make 3 hops in a row that land inside the ring. On Geographos, the speed that would launch you into space is only about 160 cm per second, so a soft, repeatable push wins. Ideas: a launch stop, softer bands, a wider base, or bumpers so it doesn't tumble.

WHAT WENT WRONG (OR COULD BE BETTER)?

THE ONE THING WE'LL CHANGE:

SKETCH VERSION 2

Retest result: _____

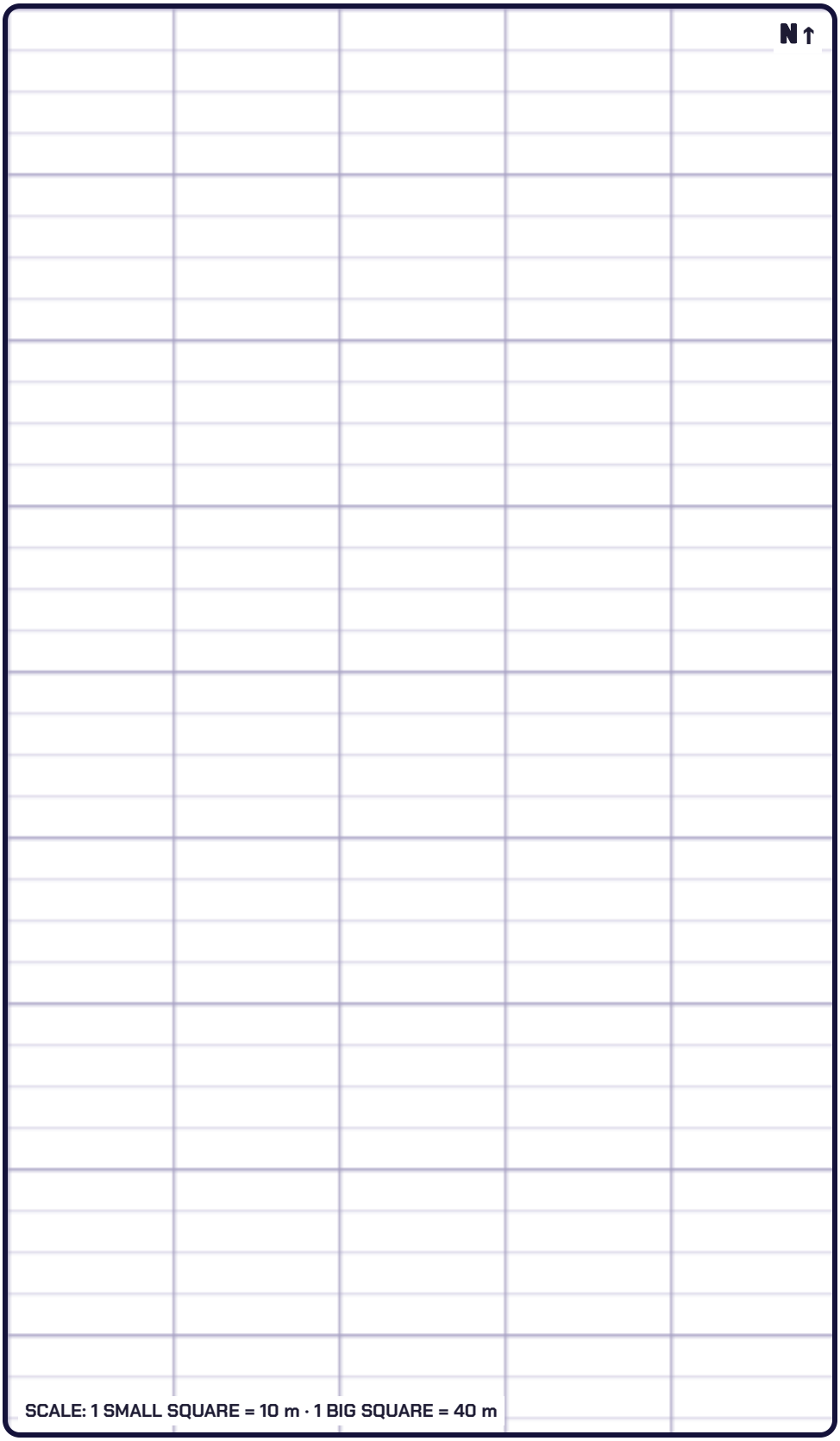
SCORE

OUTPOST DESIGNER

Design Your Outpost

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

SAMPLE EDITION



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.
- [ ] Draw **batteries** for the night side.
- [ ] Draw **rover roads** (dashed lines).
- [ ] Mark **anchor points** with ⚓.

CHECK YOUR PLAN

Longest rover road: _____ m

Habitat to pad: _____ m

Outpost name:

_____

MATH SHEET 01

The Escape Speed Challenge

On Geographos, one push could send you into space

SAMPLE EDITION

THE RULE FOR THIS PAGE

On Geographos, gravity is so weak (about **1/10,000** of Earth's) that a jump would not just go higher: if you leave the ground faster than the **escape speed**, you never come back down! Kit calculation from Geographos's mass and size: escape speed ≈ **1.6 m/s**.

1 Write the escape speed in **km per hour**. (Multiply m/s by 3.6.)

ANSWER

2 A person walks at about **1.4 m/s**. Is that faster or slower than Geographos's escape speed? What could happen if you tripped and pushed off?

ANSWER

3 A crew member weighs **80 pounds** on Earth. About how much would they weigh on Geographos?

ANSWER

4 Suppose you jump straight up at **1 m/s** (a small hop). Would you fall back down or float away from Geographos? Explain using the escape speed.

ANSWER

YOUR TURN: HOW FAST DO YOU MOVE?

Mark 10 meters outdoors. Time yourself walking, then running (with a grown-up). Speed = 10 ÷ seconds.

	TIME FOR 10 M (S)	MY SPEED (M/S)	FASTER THAN GEOGRAPHOS ESCAPE SPEED?
Walking			
Running			

5 **Engineer's question:** How would your crew move around safely when one push could send you into space? Name two things you'd build.

ANSWER

MATH SHEET 02

Travel Time & Signal Delay

Big distances, long trips, slow messages

SAMPLE EDITION

330 million mi
Shortest simple route to Geographos (kit calculation, rounded)

186,000 mi/s
About how fast radio signals (light) travel

2.7 million mi – 250 million mi
Closest and farthest distance between Earth and Geographos (rounded)

1 A fast chemical rocket on the shortest route takes about **0.6 years** to reach Geographos. How many months is that?

ANSWER

2 The route is about 330 million mi in about 0.6 years. About how many miles is that **per year**? About how many **per day**? (Use 365 days per year.)

ANSWER

3 **Signal delay:** When Geographos is closest (2.7 million mi away), how many seconds does a radio message take to arrive?

ANSWER

4 When Geographos is farthest (250 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 Geographos day is about 5 h 13 min. How many minutes is that? About how many Geographos days fit in one Earth day (1,440 minutes)?

ANSWER

6 **Game ships:** How many more years does the Ion Glider (2 years) take than the Blaze-1 (1 year)? Would you trade that time for the extra cargo? Why?

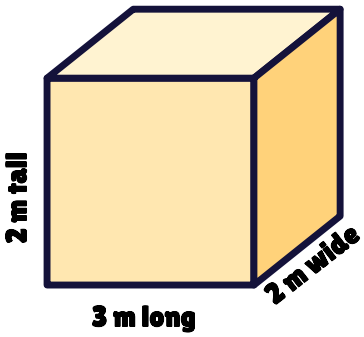
ANSWER

MATH SHEET 03

Fill Your Cargo Hold

How much Geographos metal can your ship carry?

SAMPLE EDITION



FACTS YOU NEED

Volume of a box = length × width × height.
Geographos's density is about **2,700 kg per cubic meter** (assumed (a guess)).
Suppose **5% to 10%** of the material is useful metal (practice numbers, not measurements).
Geographos's gravity ≈ **1/10,000** of Earth's.

1 What is the volume of the cargo hold (3 m × 2 m × 2 m)?

ANSWER

2 If you fill it with Geographos material at 2,700 kg per m³, what is the **mass** of the load?

ANSWER

3 If the material is **5% metal**, how many m³ of metal are in the hold? What if it's **10%**?

ANSWER

4 On Geographos, about how heavy would the full load **feel** (compared to lifting kilograms on Earth)? Hint: divide by 10,000.

ANSWER

5 **Tricky!** The load feels light on Geographos. 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 (M³)	MASS AT 2,700 KG/M³
Design 1					
Design 2					

Crew Logbook: Days 1–3

Engineers write everything down

SAMPLE EDITION

DAY 1 Briefing & trip plan

Date: _____

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

Today's win: _____ Problem we hit: _____

DAY 2 Drill rig & magnet sorter

Date: _____

Prompt: What did your cores show was inside Geographos? 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: _____

Crew Logbook: Days 4–5

Finish strong and look back

SAMPLE EDITION

DAY 4 Hopper Bot

Date: _____

Prompt: How many hops in a row landed in the ring? What did you change in version 2?

Today's win: _____ Problem we hit: _____

DAY 5 Outpost design & crew review

Date: _____

Prompt: Describe your outpost. Which challenge would you redo, and what would you change?

Today's win: _____ Problem we hit: _____

DRAW YOUR OUTPOST CREW PATCH

FUTURE JOBS

Jobs at the Outpost

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

SAMPLE EDITION

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 15 seconds to 22 min 18 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

Hopper Pilot

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 _____

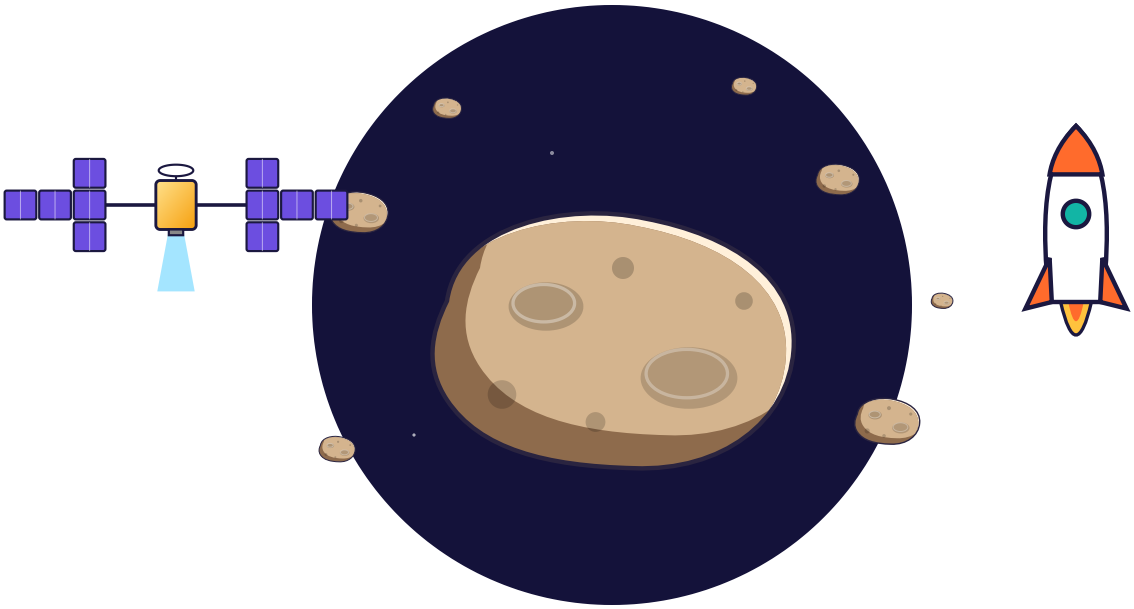
because _____

One thing I can start learning this year: _____

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

SAMPLE EDITION

OUTPOST KITS · GEOGRAPHOS.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 hopper bot, and designed a working outpost on near-Earth asteroid (Apollo, S-type) **1620 Geographos**.

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 1620 Geographos 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 Geographos 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 Hopper Bot; 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.
- **Rubber bands:** keep faces away from snapping bands during the Hopper Bot challenge.
- **Heat:** keep lamps at least 30 cm from builds, and never leave a lamp unattended.
- **String:** never around necks or wrists.
- **Speed test:** outdoors on flat ground, with clear space and supervision.

Answer Key

Worked answers for grown-ups

SAMPLE EDITION

Crew Briefing 01

1. Inner Solar System. 2. About 4.6 (24 ÷ 5.22 h). 3. About 7.2 (10 ÷ 1.39).

Crew Briefing 02

Between 0.5 and 1 buckets.

Choose Your Ship

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

Fuel Budget

	BLAZE-1	ION	COMBO
Total used	86	43	63
Fuel left	14	57	37
Pass reserve?	Yes	Yes	Yes
Tonnes home	4	47	27

Q1 Blaze-1. Q2 Ion Glider, 47 tonnes. Q3 Without the flyby, each total is 10 higher (96, 53, 73); Ion Glider and Combo Hauler still pass. Q4 9,500 m/s. Q5 About 317 times.

Plot Your Route

Divide 327 by your string length in cm. We can't fly straight because Earth, Earth and Geographos are all moving; the ship must curve to meet them.

Briefing 03

Answers vary. Example: a spectrometer to learn what it's made of; design for the worst case so the outpost is safe even if the guess is wrong.

Math Sheet 1

1. 5.7 km/h. 2. Walking (1.4 m/s) is slower than 1.6 m/s. 3. 80 ÷ 10,000 ≈ 0.0080 lb. 4. Fall back (slowly): 1 m/s is less than the escape speed. 5. Examples: tethers, handrails, anchors, nets, slow thrusters.

Math Sheet 2: Travel

1. 0.6 × 12 ≈ 7.2 months. 2. ≈ 550 million mi per year; ≈ 1,500,000 miles per day. 3. 2,700,000 ÷ 186,000 ≈ 15 seconds. 4. ≈ 22 min 24 s one way; round trip ≈ 44 min 48 s. 5. About 313 minutes; 1,440 ÷ 313 ≈ 4.6. 6. 1 years; answers vary.

Math Sheet 3: Cargo

1. 12 m³. 2. 12 × 2,700 = 32,400 kg. 3. 5%: 0.60 m³; 10%: 1.2 m³. 4. 32,400 ÷ 10,000 ≈ 3.2 kg. 5. Yes. The mass stays 32,400 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; softer, repeatable pushes land in the ring more often than hard ones.

Sources & Fact Notes

Where every real number came from

SAMPLE EDITION

Facts about Geographos 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 JPL Solar System Dynamics, "Small-Body Database Lookup: 1620 Geographos."**
   ssd.jpl.nasa.gov/tools/sbdb_lookup.html#/?sstr=1620
2. **Wikipedia, "1620 Geographos."**
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3. **Wikipedia, "National Geographic Society – Palomar Observatory Sky Survey."**
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   en.wikipedia.org/wiki/Clementine_(spacecraft)
5. **Wikipedia, "Goldstone Deep Space Communications Complex."**
   en.wikipedia.org/wiki/Goldstone_Deep_Space_Communications_Complex
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7. **Wikipedia, "Yarkovsky effect."**
   en.wikipedia.org/wiki/Yarkovsky_effect
8. **NASA NSSDCA, "Planetary Fact Sheet (orbit comparison)."**
   nssdc.gsfc.nasa.gov/planetary/factsheet
9. **Elsevier, "Carry, B. (2012). Density of asteroids. Planetary and Space Science 73, 98–118."**
   doi.org/10.1016/j.pss.2012.03.009
10. **NASA/JPL Solar System Dynamics, "JPL Small-Body Database (SBDB) API record."**
    ssd-api.jpl.nasa.gov/sbdb.api?sstr=1620&phys-par=1
11. **NASA Science, "Moon Facts (surface gravity about one-sixth of Earth's)."**
    science.nasa.gov/moon/facts
12. **Speed of light and radio, about 186,000 miles per second:** a standard physical constant, rounded.

About this kit. Geographos Outpost Kit, Sample edition, by Outpost Kits (10timesIt LLC) · geographos.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.