SAMPLE EDITION

IPHIGENIA OUTPOST KIT

MINOR PLANET No.
112

Travel to main-belt asteroid (dark, carbonaceous) 112 Iphigenia. Harvest ice. 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 Iphigenia Outpost Kit

SAMPLE EDITION

You're on the build crew!

Imagine a future where people travel to **112 Iphigenia**, main-belt asteroid (dark, carbonaceous). You've been picked for the **first construction crew**. Your jobs: **plan the trip, get there, harvest ice and water, 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 Iphigenia. No spacecraft has visited Iphigenia 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: _____

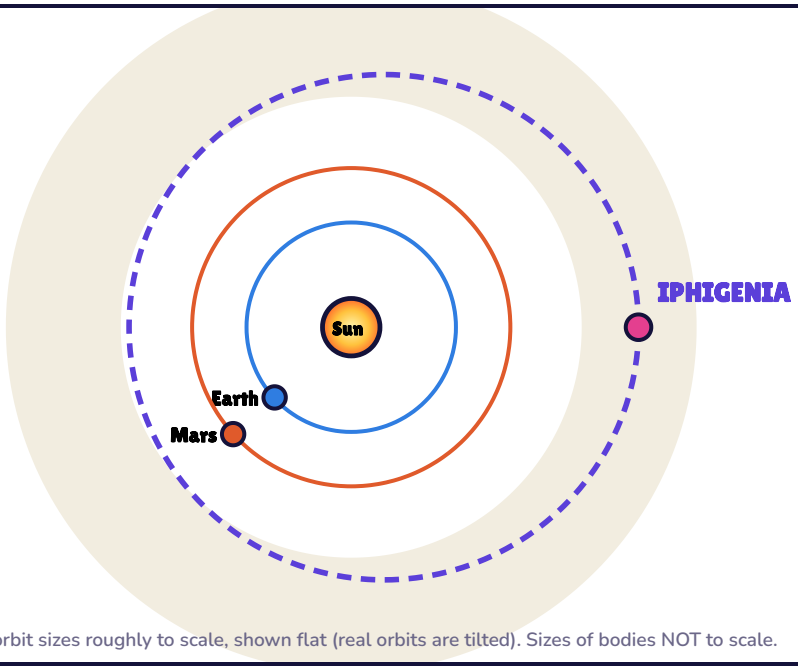
Sample edition of a printable kit (full kit $29 at iphigenia.space). Grown-ups: please read the Parent & Teacher Guide and safety notes before building. Not affiliated with or endorsed by NASA, JPL, ESA, JAXA or any space agency.

CREW BRIEFING 01

SAMPLE EDITION

Where Is Iphigenia?

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.

~2.4×
farther from the Sun than Earth is, on average. Iphigenia's distance from the Sun: 197–255 million miles (2.1–2.7 AU).

103–350
million miles between Earth and Iphigenia. 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).

≈ 3.8 years
for Iphigenia to orbit the Sun once (about 1,387 Earth days). That's one Iphigenia "year."

31 h 28 min
for Iphigenia to spin once: a Iphigenia "day."

1870
Discovered: Sept. 19, 1870 by C. H. F. Peters, Litchfield Observatory, Clinton, NY

CREW CHECK

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

2. How many Earth days long is one Iphigenia day? About _____

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

CREW BRIEFING 02

SAMPLE EDITION

What Is Iphigenia Made Of?

Size, stuff, density, and gravity

A dark, carbon-rich world

Iphigenia is about **69.8 km (43 miles)** across (JPL). Asteroids like this are called **C-type** (carbon-rich). They are very dark. Meteorites and samples from bodies like this contain **clay minerals that hold water**, plus carbon compounds.

What scientists have found

- ☐ Iphigenia is described as fairly large and exceedingly dark.
- ☐ JPL lists a diameter of about 70 km and a geometric albedo of just 0.042: it reflects only about 4% of the light that hits it.
- ☐ It is classed as a C-type asteroid, so it probably has a primitive carbon-rich composition.

Its density is about **1,400 kg per cubic meter** (assumed (a guess)). Water is 1,000 kg per cubic meter, so Iphigenia material is about 1.4× as dense as water. Nobody has measured it; this number is borrowed from similar bodies.

GRAVITY: VERY WEAK

Iphigenia's surface gravity is about **1/720** of Earth's. A crew member who weighs 80 lb on Earth would weigh only about **0.11 lb**. Throw a ball faster than about **31 m/s** (69 mph) and it never comes back!

Kit calculation: g = 0.014 m/s² from mass (assumed density) and diameter. Earth's is 9.8 m/s².

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

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

What this means for builders

IPHIGENIA FACT	ENGINEERING PROBLEM
Gravity ≈ 1/720 of Earth's	Push too hard and you float away, so use **tethers & anchors**.
Ice and rock mixed together	Need a way to **melt ice and clean the water**.
31 h 28 min day	Sunlight comes and goes, so **store power**.
~2.4× farther from the Sun	Sunlight is about **6× weaker**, so solar panels make less power.
About -95 °C (-140 °F)	Habitats need **heaters and insulation**.

CREW CHECK

Suppose 10% to 30% of the material you dig on Iphigenia is useful ice (a practice number, not a measurement). If you dig up 10 buckets, between _____ and _____ buckets could be ice.

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

CREW BRIEFING 03

How Do We Know?

Clues, measurements, and mysteries about Iphigenia

SAMPLE EDITION

Timeline: how we found out

1870 **Discovered:** Sept. 19, 1870 by C. H. F. Peters, Litchfield Observatory, Clinton, NY

1871 **First orbit published:** 1871, by Friedrich Tietjen

EVIDENCE BOARD

FACT	VALUE	HOW SURE?
Size	69.8 km	MEASURED
Density	1.4 g/cm³	GUESS
Mass	2.5e+17 kg	GUESS
Spin (day length)	31 h 28 min	MEASURED
Orbit	tracked by JPL	MEASURED
Temperature	≈ -95 °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 IPHIGENIA

_____

_____

_____

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: Iphigenia'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?

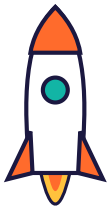
SAMPLE EDITION

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 Iphigenia (about 1.1 years for a quick chemical rocket).

BLAZE-1

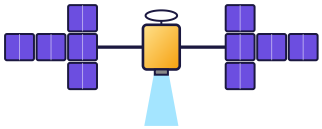
Chemical rocket ship



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

ION GLIDER

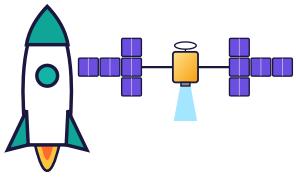
Solar electric ship



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 water ice** home? (Find out on the Fuel Budget page.)

MY CREW'S CHOICE

We choose: _____

Because:

One risk of our choice is:

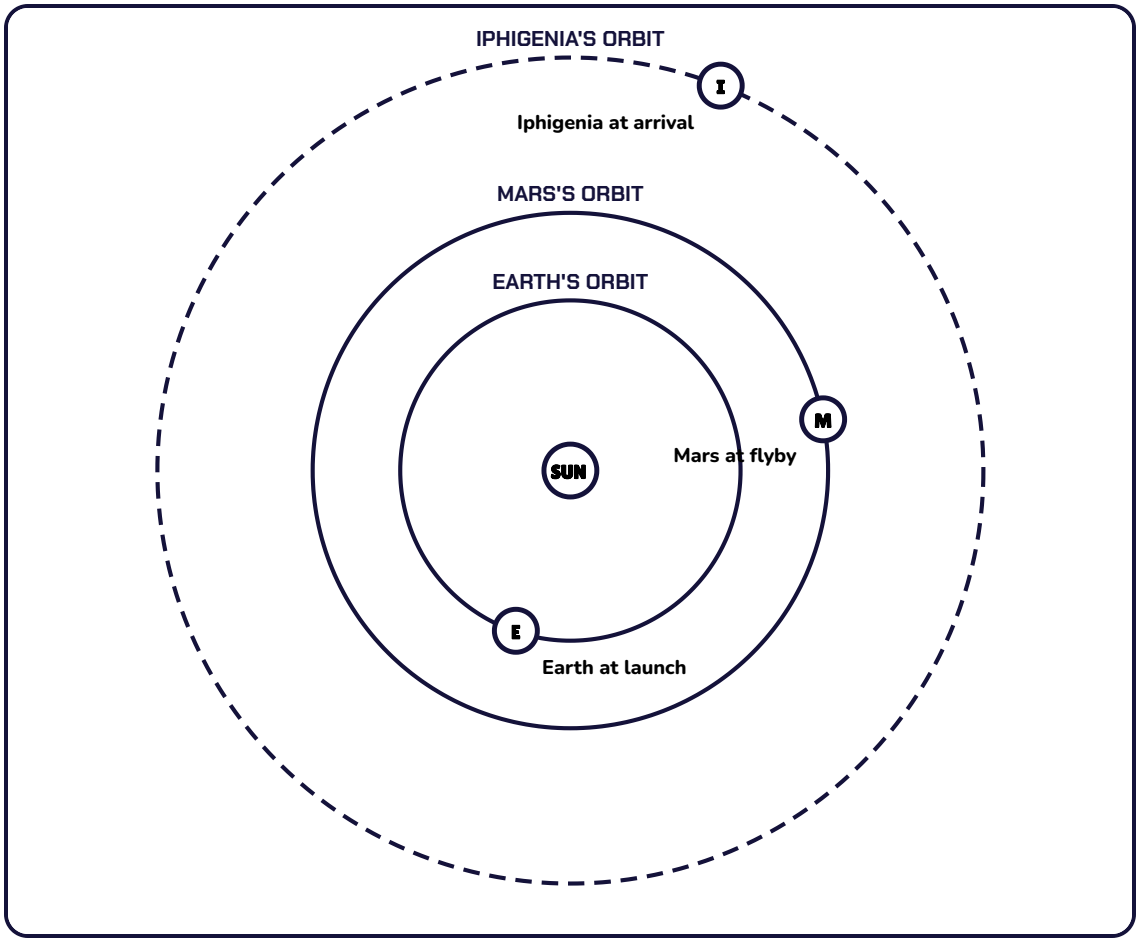
DESIGN A PATCH FOR YOUR SHIP

PLAN YOUR TRIP 02

Plot Your Route

Draw your path from Earth to Iphigenia

SAMPLE EDITION



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 Iphigenia at **I**.
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 Iphigenia is about 479 million miles (kit calculation; real routes are often longer). On my map, 1 cm stands for about _____ million miles.

Hint: 479 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 water ice home.

TRIP LEG	BLAZE-1	ION GLIDER	COMBO HAULER
Leave Earth's orbit	27	14	18
Cruise to Mars	18	9	14
Mars gravity assist (free boost: SUBTRACT)	−10	−10	−10
Cruise to Iphigenia	27	18	23
Brake into orbit at Iphigenia	18	9	14
Land and hop to the mine site	5	5	5
TOTAL FUEL USED			
FUEL LEFT (100 – total)			
Pass the 10-point reserve? (yes / no)			
Tonnes of water ice 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 water ice? How many tonnes?

ANSWER

3 What if you skipped the Mars 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 Iphigenia needs about **9.2 km/s** (no gravity assists).

4 How many meters per second is 9.2 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

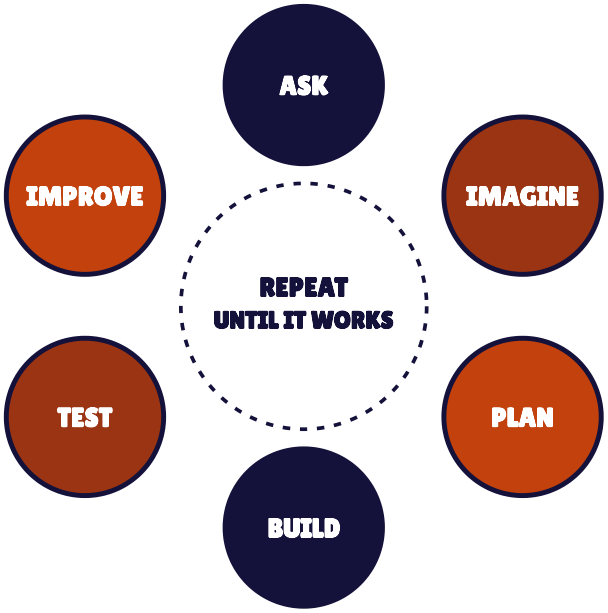
CREW MEMO: WHICH SHIP DO WE PICK NOW, AND WHY?

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.
- [ ] Never drink water you harvested or filtered in a challenge.
- [ ] 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

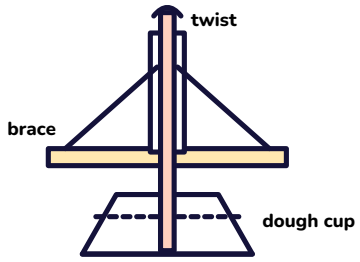
Pull a sample from deep inside Iphigenia

SAMPLE EDITION

WHY IPHIGENIA NEEDS THIS

Before mining, crews must know what is **under** the surface. A core drill pulls out a tube of layers. On Iphigenia, gravity is so weak (about **1/720** 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 white beads ("ice nuggets")
- ☐ Ruler, marker, child-safe scissors

BUILD STEPS

1. **Make Iphigenia:** a partner presses 3 colored dough layers into the cup and hides bead 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 ice.

CORE #	DEPTH (CM)	LAYERS / COLORS SEEN	ICE 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 Iphigenia 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 Iphigenia'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

Ice & Water Harvester

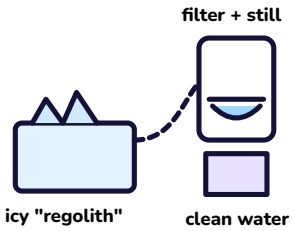
Turn dirty ice into clean water

SAMPLE EDITION

WHY IPHIGENIA NEEDS THIS

Water is the most useful thing a crew can find: you can drink it, grow food with it, and split it into **oxygen** and **rocket fuel**. Iphigenia's dark rock likely holds water locked inside clay minerals. Your harvester must melt it and get the dirt out.

ONE WAY TO BUILD IT



MATERIALS

- [ ] 2 cups of crushed ice mixed with 2 spoons of sand or soil ("icy regolith")
- [ ] Clear plastic cup + a second cup
- [ ] Coffee filter or paper towel
- [ ] Rubber band
- [ ] A clean jar
- [ ] Desk lamp or sunny window
- [ ] Plastic wrap
- [ ] Measuring cup or ruler
- [ ] Timer

BUILD STEPS

1. Mix the ice and sand in a bowl. This is your **icy regolith**.
2. Stretch the coffee filter over a cup with a rubber band: this is your **filter**.
3. Put a scoop of icy regolith in another cup, cover with plastic wrap, and place it in the sun or under the lamp (30 cm away).
4. When it has melted, pour the muddy water slowly through the filter.
5. Pour it through a second clean filter if it is still cloudy.
6. Measure how much clean-looking water you collected.

SAFETY

Lamps get hot: keep paper and plastic away from the bulb. Never drink your harvested water.

BLUEPRINT: SKETCH AND LABEL YOUR DESIGN BEFORE YOU BUILD

CHALLENGE 2 · TEST + IMPROVE

Ice & Water Harvester

Test it, record it, make it better

SAMPLE EDITION

Test it

Run 3 batches. Measure how much water you collect and how clear it looks (0 = mud, 5 = crystal clear). **Do not drink it!**

BATCH	MELT TIME (MIN)	WATER COLLECTED (ML)	CLARITY (0–5)	NOTES
1				
2				
3				

PREDICT BEFORE YOU TEST

I think our design will _____

Improve it: redesign

REDESIGN CHALLENGE

Get **more, clearer water** faster. Ideas: a black cup to soak up heat, a foil reflector, layers of sand and gravel in your filter, or a second filter stage. On Iphigenia, the temperature is about -95 °C (-140 °F), so heat is precious!

WHAT WENT WRONG (OR COULD BE BETTER)?

THE ONE THING WE'LL CHANGE:

SKETCH VERSION 2

Retest result: _____

SCORE

CHALLENGE 3 · BUILD

Shielded Habitat

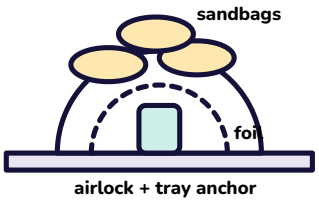
A home that survives low gravity and radiation

SAMPLE EDITION

WHY IPHIGENIA NEEDS THIS

Iphigenia has **no air** and no thick atmosphere to block harsh space radiation, and its 31 h 28 min days mean sunlight and shadow come and go. It is cold there: about -95 °C (-140 °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"

SAFETY

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

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.

BLUEPRINT: SKETCH AND LABEL YOUR DESIGN BEFORE YOU BUILD

CHALLENGE 3 · TEST + IMPROVE

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

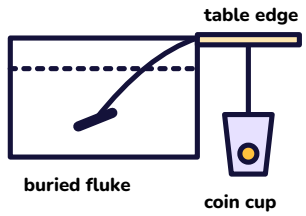
Keep your crew and gear from floating off

SAMPLE EDITION

WHY IPHIGENIA NEEDS THIS

With gravity only about **1/720 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

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

Mini Cargo Rover

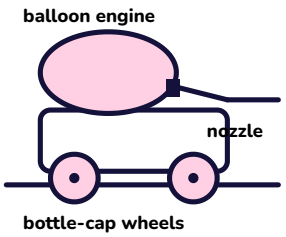
Haul cargo from the mine to the base

SAMPLE EDITION

WHY IPHIGENIA NEEDS THIS

Rovers carry ore around the outpost. A radio signal takes about **9 min 15 s to 31 min 17 s** to travel one way between Earth and Iphigenia, 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

CHALLENGE 5 · TEST + IMPROVE

Mini Cargo Rover

Test it, record it, make it better

SAMPLE EDITION

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

OUTPOST DESIGNER

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 — Ice dig site + drill rigs
- WATER — Water plant: melts and cleans ice
- HAB — Habitat: where the crew lives
- ROV — Rover garage + charging
- PAD — Landing pad
- STORE — Water + fuel tanks

DESIGN RULES

- ☐ Put the **water plant near the dig site** to save 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 Iphigenia is about **6× 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:

_____

MATH SHEET 01

Jump Height on Iphigenia

How high can you leap when gravity is ~1/720 of Earth's?

SAMPLE EDITION

THE RULE FOR THIS PAGE

Iphigenia's gravity is about **1/720** of Earth's (kit calculation from its mass and size). If you push off just as hard, your jump goes about **720 times higher** and keeps you in the air about **720 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 Iphigenia? 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 Iphigenia?

ANSWER

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

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)	× 6 = ON THE MOON (CM)	× 720 = ON IPHIGENIA (CM)	IPHIGENIA JUMP IN METERS
Try 1				
Try 2				

5 **Engineer's question:** A 220-meter jump sounds fun, but why could it be dangerous at an outpost? Name one thing you'd build to fix it.

ANSWER

MATH SHEET 02

Travel Time & Signal Delay

Big distances, long trips, slow messages

SAMPLE EDITION

480 million mi
Shortest simple route to Iphigenia (kit calculation, rounded)

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

100 million mi – 350 million mi
Closest and farthest distance between Earth and Iphigenia (rounded)

1 A fast chemical rocket on the shortest route takes about **1.1 years** to reach Iphigenia. How many months is that?

ANSWER

2 The route is about 480 million mi in about 1.1 years. About how many miles is that **per year**? About how many **per day**? (Use 365 days per year.)

ANSWER

3 **Signal delay:** When Iphigenia is closest (100 million mi away), how many seconds does a radio message take to arrive?

ANSWER

4 When Iphigenia is farthest (350 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 Iphigenia day is about 31 h 28 min. How many minutes is that? About how many Iphigenia 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?

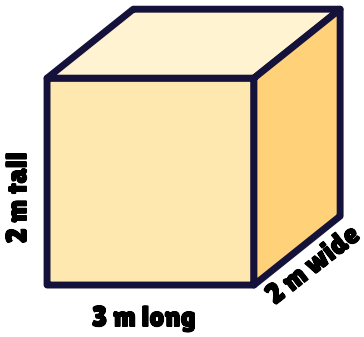
ANSWER

MATH SHEET 03

Fill Your Cargo Hold

How much Iphigenia water ice can your ship carry?

SAMPLE EDITION



FACTS YOU NEED

Volume of a box = length × width × height.
Iphigenia's density is about **1,400 kg per cubic meter** (assumed (a guess)).
Suppose **10% to 30%** of the material is useful water ice (practice numbers, not measurements).
Iphigenia's gravity ≈ **1/720** 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 Iphigenia material at 1,400 kg per m³, what is the **mass** of the load?

ANSWER

3 If the material is **10% water ice**, how many m³ of water ice are in the hold? What if it's **30%**?

ANSWER

4 On Iphigenia, about how heavy would the full load **feel** (compared to lifting kilograms on Earth)? Hint: divide by 720.

ANSWER

5 **Tricky!** The load feels light on Iphigenia. 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 1,400 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 Iphigenia?

Today's win: _____ Problem we hit: _____

DAY 2 Drill rig & ice harvester

Date: _____

Prompt: What did your cores show was inside Iphigenia? How much clean water did your harvester collect, 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 Mini Cargo Rover

Date: _____

Prompt: How far did your rover go with cargo on the towel? 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

Ice Miner

At the outpost: Finds, digs, and melts ice, then turns water into drinking water, air, and rocket fuel.
What to learn: Geology, chemistry, math (volume and mass), safety planning
Real today: **Mining engineers**, **geologists** and **water engineers** 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 9 min 15 s to 31 min 17 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 _____

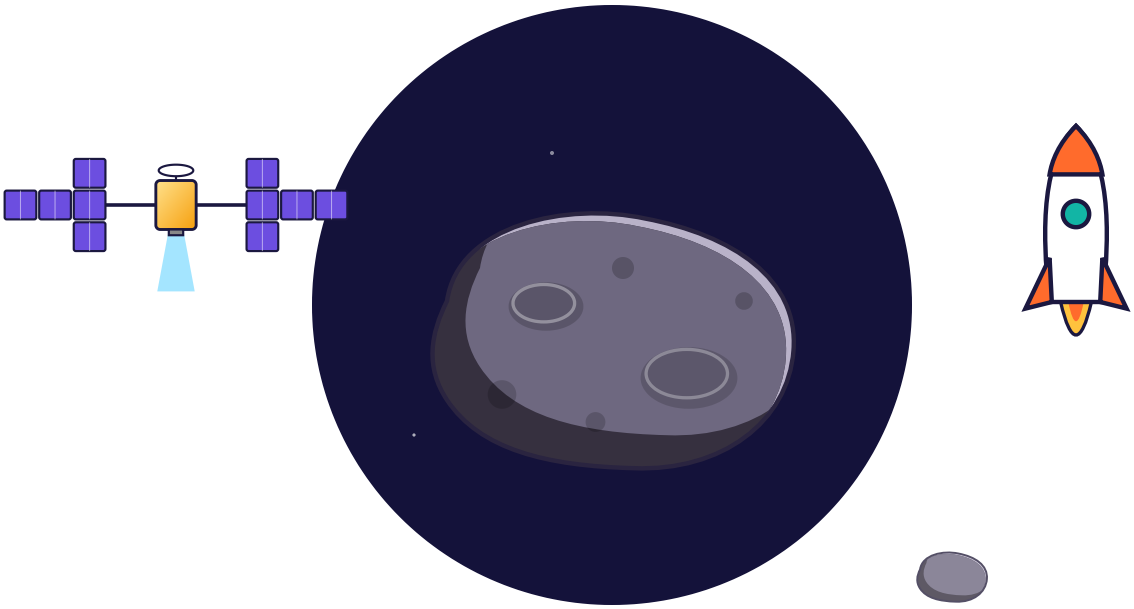
because _____

One thing I can start learning this year: _____

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

SAMPLE EDITION

OUTPOST KITS · IPHIGENIA.SPACE



OUTPOST CREW
CERTIFICATE

This certifies that

_____

planned the trip, budgeted the fuel, built and improved a core drill rig, an ice and water harvester, a shielded habitat, a tether and anchor system, and a mini cargo rover, and designed a working outpost on main-belt asteroid (dark, carbonaceous) **112 Iphigenia**.

Crew role: _____

_____ _____

Outpost Commander (grown-up) Date

SAMPLE EDITION

Parent & Teacher Guide

Objectives, schedule, and safety

Learning objectives

- ☐ Use the engineering design process: define a problem, then build, test, and **improve** a design based on data.
- ☐ Explain what and where 112 Iphigenia 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 Iphigenia 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 Ice & Water Harvester; 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.
- **Water:** harvested or filtered water from Challenge 2 is not safe to drink. Wipe up spills.
- **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. Inner main belt. 2. About 1.3 (31.5 h ÷ 24). 3. About 2.6 (10 ÷ 3.80).

Crew Briefing 02

Between 1 and 3 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	85	45	64
Fuel left	15	55	36
Pass reserve?	Yes	Yes	Yes
Tonnes home	5	45	26

Q1 Blaze-1. Q2 Ion Glider, 45 tonnes. Q3 Without the flyby, each total is 10 higher (95, 55, 74); Ion Glider and Combo Hauler still pass. Q4 9,200 m/s. Q5 About 307 times.

Plot Your Route

Divide 479 by your string length in cm. We can't fly straight because Earth, Mars and Iphigenia 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. 30 × 720 = 21,600 cm = 216 m. 2. 0.5 × 720 = 360 seconds. 3. Moon: 30 × 6 = 180 cm; 21,600 ÷ 180 ≈ 120. 4. 4,000 ÷ 720 ≈ 5.6 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. 1.1 × 12 ≈ 13 months. 2. ≈ 440 million mi per year; ≈ 1,200,000 miles per day. 3. 100,000,000 ÷ 186,000 ≈ 8 min 58 s. 4. ≈ 31 min 22 s one way; round trip ≈ 62 min 43 s. 5. About 1,888 minutes; 1,440 ÷ 1,888 ≈ 0.76. 6. 1 years; answers vary.

Math Sheet 3: Cargo

1. 12 m^3. 2. 12 × 1,400 = 16,800 kg. 3. 10%: 1.2 m^3; 30%: 3.6 m^3. 4. 16,800 ÷ 720 ≈ 23 kg. 5. Yes. The mass stays 16,800 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; a second filter and a dark cup usually give clearer water faster; wider or treaded wheels usually help on the towel.

Sources & Fact Notes

Where every real number came from

SAMPLE EDITION

Facts about Iphigenia 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: 112 Iphigenia."**
   ssd.jpl.nasa.gov/tools/sbdb_lookup.html#/?sstr=112
2. **Wikipedia, "112 Iphigenia."**
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3. **Wikipedia, "Christian Heinrich Friedrich Peters."**
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   en.wikipedia.org/wiki/Light_curve
5. **NASA NSSDCA, "Planetary Fact Sheet (orbit comparison)."**
   nssdc.gsfc.nasa.gov/planetary/factsheet
6. **Elsevier, "Carry, B. (2012). Density of asteroids. Planetary and Space Science 73, 98–118."**
   doi.org/10.1016/j.pss.2012.03.009
7. **NASA/JPL Solar System Dynamics, "JPL Small-Body Database (SBDB) API record."**
   ssd-api.jpl.nasa.gov/sbdb.api?sstr=112&phys-par=1
8. **NASA Science, "Moon Facts (surface gravity about one-sixth of Earth's)."**
   science.nasa.gov/moon/facts
9. **Speed of light and radio, about 186,000 miles per second:** a standard physical constant, rounded.

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