SAMPLE EDITION

RYUGU OUTPOST KIT

MINOR PLANET No.
162173

Travel to near-Earth asteroid (C-type) 162173 Ryugu. 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 Ryugu Outpost Kit

SAMPLE EDITION

You're on the build crew!

Imagine a future where people travel to **162173 Ryugu**, near-Earth asteroid (C-type). 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 Ryugu. Robots and telescopes so far: **Spacecraft**: JAXA's Hayabusa2 — arrived June 27, 2018; samples returned December 2020. 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: _____

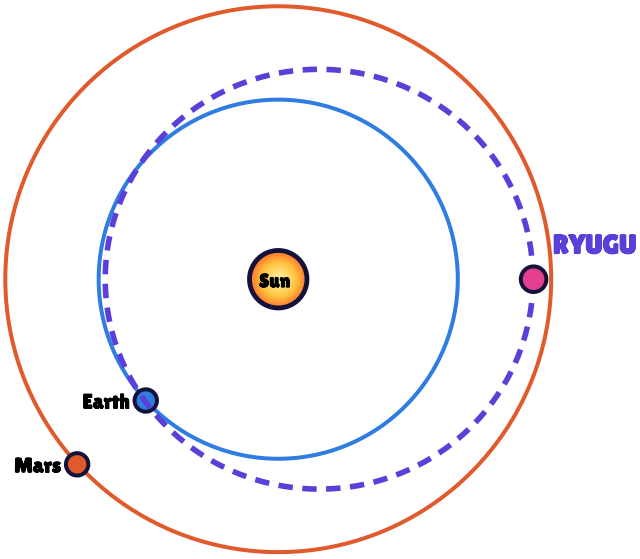
Sample edition of a printable kit (full kit $29 at ryugu.space). Grown-ups: please read the Parent & Teacher Guide and safety notes before building. Not affiliated with or endorsed by NASA, JPL, ESA, JAXA or any space agency.

CREW BRIEFING 01

Where Is Ryugu?

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. Ryugu's distance from the Sun: 89.6–132 million miles (1–1.4 AU).

226 M
miles: the most that can separate Earth and Ryugu. The two orbits can come as close as 50,000 miles!

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

≈ 1.3 years
for Ryugu to orbit the Sun once (about 475 Earth days). That's one Ryugu "year."

7 h 38 min
for Ryugu to spin once: a Ryugu "day." Sunrise to sunrise in about 7.6 hours!

1999
Discovered: May 10, 1999 — LINEAR survey, Socorro, New Mexico

CREW CHECK

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

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

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

CREW BRIEFING 02

SAMPLE EDITION

What Is Ryugu Made Of?

Size, stuff, density, and gravity

A dark, carbon-rich world

Ryugu is about **896 m (2,940 feet)** across (Hayabusa2 shape model (Watanabe et al. 2019)). 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

- ☐ Its bulk density is only about 1.19 g/cm³, and JAXA scientists concluded that it is a rubble pile with roughly half of its volume made of empty space.
- ☐ The surface is extremely dark, reflecting only about 4.5% of the sunlight that hits it.
- ☐ Ryugu's grains turned out to be rich in water-bearing minerals, with a measured water content of about 6.8% by weight, and chemically similar to the rare CI chondrite meteorites.

Its density is about **1,200 kg per cubic meter** (measured). Water is 1,000 kg per cubic meter, so Ryugu material is about 1.2× as dense as water.

GRAVITY: ALMOST ZERO

Ryugu's gravity is **tiny**: about **1/66,000** of Earth's. A gentle jump could launch you off into space, because the **escape speed** is only about **37 cm per second** (0.82 mph).

Kit calculation: g = 0.00015 m/s² from mass and diameter. Earth's is 9.8 m/s².

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

Use real pictures from the spacecraft to help you.

What this means for builders

RYUGU FACT	ENGINEERING PROBLEM
Gravity ≈ 1/66,000 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**.
7 h 38 min day	Sunlight comes and goes, so **store power**.
About -19 °C (-2 °F)	Habitats need **heaters and insulation**.
No air, harsh space radiation	Habitats need **sealed walls and thick shielding**.

CREW CHECK

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

Facts: Ryugu's published sources (see the Sources page). Size: sbdb; density: measured (Watanabe et al. 2019). Gravity, weight and escape speed are kit calculations.

CREW BRIEFING 03

How Do We Know?

Clues, measurements, and mysteries about Ryugu

SAMPLE EDITION

Timeline: how we found out

1999 **Discovered:** May 10, 1999 — LINEAR survey, Socorro, New Mexico

2018 **Spacecraft:** JAXA's Hayabusa2 — arrived June 27, 2018; samples returned December 2020

From the records

- ☐ Ryugu was discovered on May 10, 1999, by the LINEAR asteroid survey in Socorro, New Mexico, and carried the provisional designation 1999 JU3.
- ☐ JAXA's Hayabusa2 launched on December 3, 2014, on an H-IIA rocket and arrived at Ryugu on June 27, 2018.
- ☐ It dropped two tiny hopping rovers, HIBOU and OWL, on September 21, 2018, and the German–French MASCOT lander on October 3, 2018.

EVIDENCE BOARD

FACT	VALUE	HOW SURE?
Size	0.896 km	MEASURED
Density	1.2 g/cm³	MEASURED
Mass	4.5e+11 kg	MEASURED
Spin (day length)	7 h 38 min	MEASURED
Orbit	tracked by JPL	MEASURED
Temperature	≈ -19 °C	ESTIMATED

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

STILL A MYSTERY

- ☐ Nobody knows exactly what is under the surface.

MY QUESTIONS FOR THE NEXT SPACECRAFT TO VISIT RYUGU

_____

_____

_____

_____

_____

_____

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: Ryugu'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?

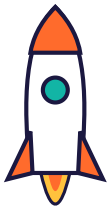
SAMPLE EDITION

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 Ryugu (about 0.6 years for a quick chemical rocket).

BLAZE-1

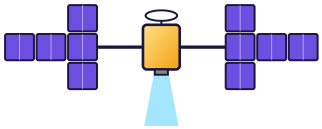
Chemical rocket ship



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

ION GLIDER

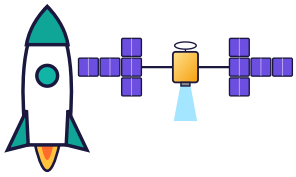
Solar electric ship



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

MY CREW'S CHOICE

We choose: _____

Because:

One risk of our choice is:

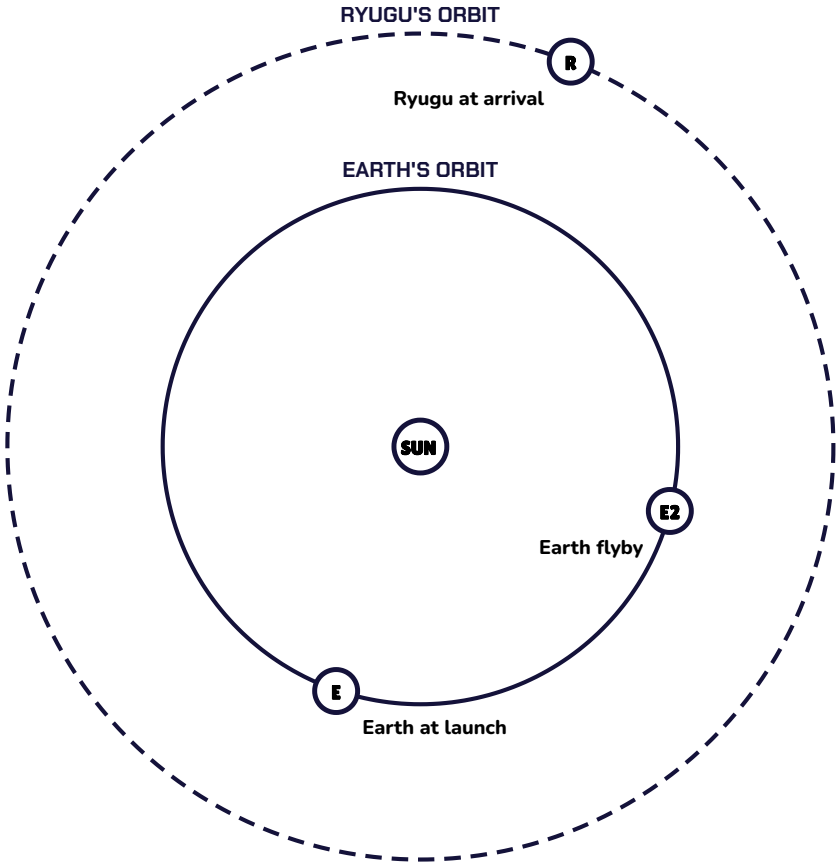
DESIGN A PATCH FOR YOUR SHIP

PLAN YOUR TRIP 02

SAMPLE EDITION

Plot Your Route

Draw your path from Earth to Ryugu



Ryugu'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 Ryugu at **R**.
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 Ryugu is about 319 million miles (kit calculation; real routes are often longer). On my map, 1 cm stands for about _____ million miles.

Hint: 319 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	19	9	12
Loop around the Sun	12	6	9
Earth gravity assist (free boost: SUBTRACT)	−10	−10	−10
Cruise to Ryugu	19	12	16
Brake to match Ryugu's speed	12	6	9
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 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 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 Ryugu needs about **6.3 km/s** (no gravity assists).

4 How many meters per second is 6.3 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

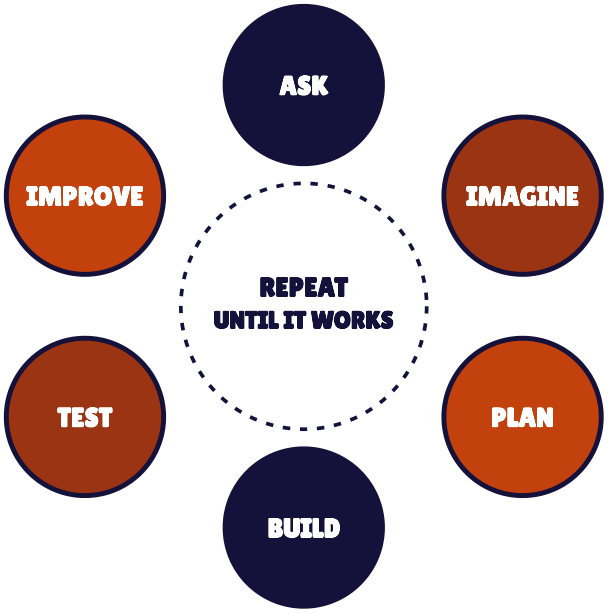
CREW MEMO: WHICH SHIP DO WE PICK NOW, AND WHY?

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

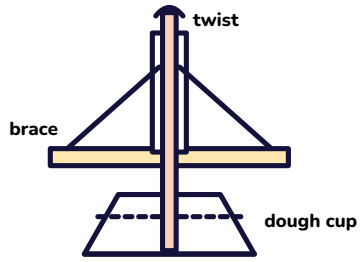
Pull a sample from deep inside Ryugu

SAMPLE EDITION

WHY RYUGU NEEDS THIS

Before mining, crews must know what is **under** the surface. A core drill pulls out a tube of layers. On Ryugu, gravity is so weak (about **1/66,000** 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 white beads ("ice nuggets")
- ☐ Ruler, marker, child-safe scissors

BUILD STEPS

1. **Make Ryugu:** 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 Ryugu 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 Ryugu'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

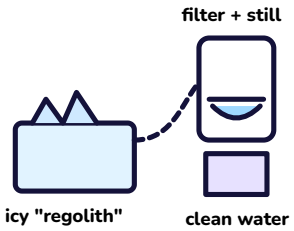
Turn dirty ice into clean water

SAMPLE EDITION

WHY RYUGU 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**. Ryugu'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 Ryugu, the temperature is about -19 °C (-2 °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

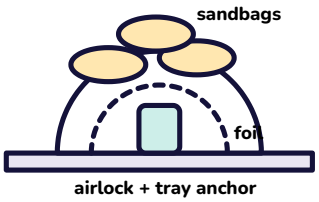
A home that survives low gravity and radiation

SAMPLE EDITION

WHY RYUGU NEEDS THIS

Ryugu has **no air** and no thick atmosphere to block harsh space radiation, and its 7 h 38 min days mean sunlight and shadow come and go fast. It is cold there: about -19 °C (-2 °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

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

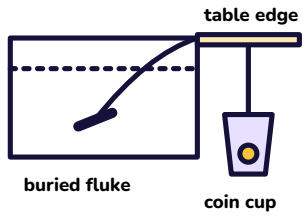
Keep your crew and gear from floating off

SAMPLE EDITION

WHY RYUGU NEEDS THIS

With gravity only about **1/66,000 of Earth's**, a gentle push faster than about **37 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

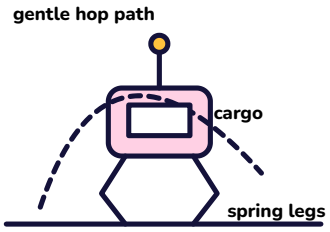
Move cargo where wheels can't grip

SAMPLE EDITION

WHY RYUGU NEEDS THIS

On Ryugu, gravity is so tiny (about 1/66,000 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 **0.3 seconds to 20 min 15 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 Ryugu, the speed that would launch you into space is only about 37 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

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.
- ☐ 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 Ryugu, one push could send you into space

SAMPLE EDITION

THE RULE FOR THIS PAGE

On Ryugu, gravity is so weak (about **1/66,000** 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 Ryugu's mass and size: escape speed ≈ **37 cm/s**.

1 Write the escape speed in **meters per second**. (100 cm = 1 m.)

ANSWER

2 A person walks at about **1.4 m/s**. Is that faster or slower than Ryugu'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 Ryugu?

ANSWER

4 Suppose you jump straight up at **1 m/s** (a small hop). Would you fall back down or float away from Ryugu? 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 RYUGU 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

320 million mi
Shortest simple route to Ryugu (kit calculation, rounded)

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

50,000 mi – 230 million mi
Closest and farthest distance between Earth and Ryugu (rounded)

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

ANSWER

2 The route is about 320 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 Ryugu is closest (50,000 mi away), how many seconds does a radio message take to arrive?

ANSWER

4 When Ryugu is farthest (230 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 Ryugu day is about 7 h 38 min. How many minutes is that? About how many Ryugu 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?

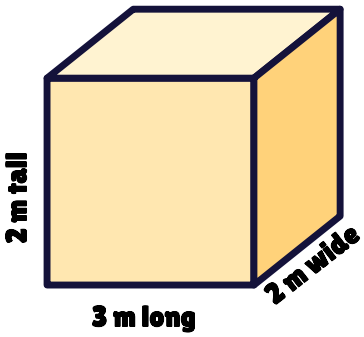
ANSWER

MATH SHEET 03

Fill Your Cargo Hold

How much Ryugu water ice can your ship carry?

SAMPLE EDITION



FACTS YOU NEED

Volume of a box = length × width × height.
Ryugu's density is about **1,200 kg per cubic meter** (measured).
Suppose **10% to 30%** of the material is useful water ice (practice numbers, not measurements).
Ryugu's gravity ≈ **1/66,000** 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 Ryugu material at 1,200 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 Ryugu, about how heavy would the full load **feel** (compared to lifting kilograms on Earth)? Hint: divide by 66,000.

ANSWER

5 **Tricky!** The load feels light on Ryugu. 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 1,200 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 Ryugu?

Today's win: _____ Problem we hit: _____

DAY 2 Drill rig & ice harvester

Date: _____

Prompt: What did your cores show was inside Ryugu? 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 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

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 0.3 seconds to 20 min 15 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 _____

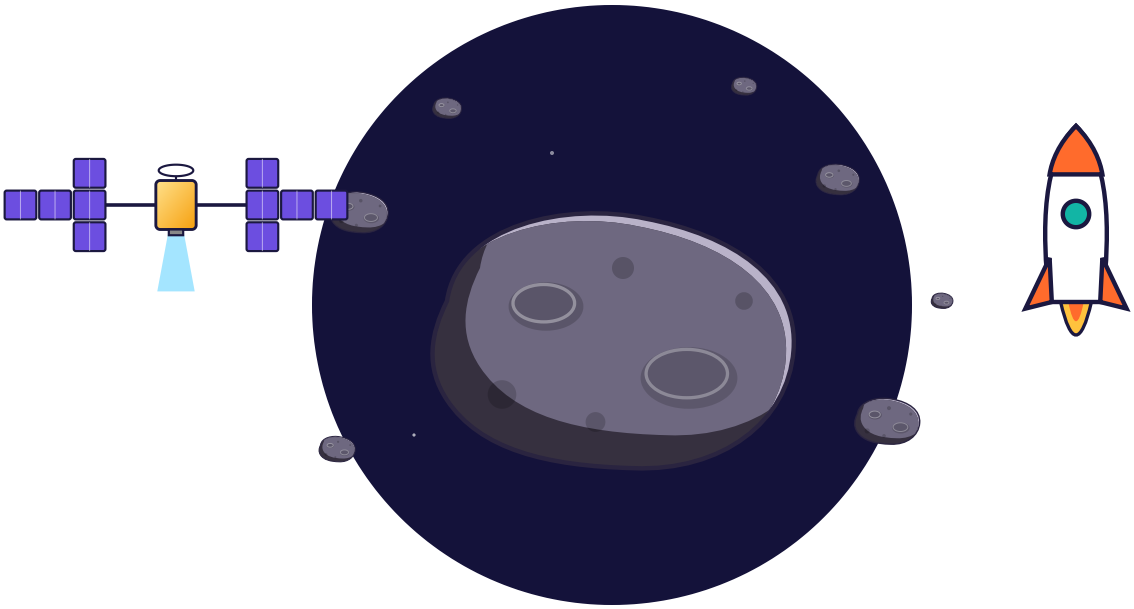
because _____

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 · RYUGU.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 hopper bot, and designed a working outpost on near-Earth asteroid (C-type) **162173 Ryugu**.

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 162173 Ryugu 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 Ryugu 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 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.
- **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.
- **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. Apollo group. 2. About 3.1 (24 ÷ 7.63 h). 3. About 7.7 (10 ÷ 1.30).

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	54	25	38
Fuel left	46	75	62
Pass reserve?	Yes	Yes	Yes
Tonnes home	36	65	52

Q1 Blaze-1. Q2 Ion Glider, 65 tonnes. Q3 Without the flyby, each total is 10 higher (64, 35, 48); Blaze-1 and Ion Glider and Combo Hauler still pass. Q4 6,300 m/s. Q5 About 210 times.

Plot Your Route

Divide 319 by your string length in cm. We can't fly straight because Earth, Earth and Ryugu 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. 0.37 m/s. 2. Walking (1.4 m/s) is faster than 0.37 m/s: a trip could send you off into space. 3. 80 ÷ 66,000 ≈ 0.0012 lb. 4. Float away: 1 m/s is faster than the escape speed. 5. Examples: tethers, handrails, anchors, nets, slow thrusters.

Math Sheet 2: Travel

1. 0.6 × 12 ≈ 7.2 months. 2. ≈ 530 million mi per year; ≈ 1,500,000 miles per day. 3. 50,000 ÷ 186,000 ≈ 0.3 seconds. 4. ≈ 20 min 37 s one way; round trip ≈ 41 min 13 s. 5. About 458 minutes; 1,440 ÷ 458 ≈ 3.1. 6. 1 years; answers vary.

Math Sheet 3: Cargo

1. 12 m^3. 2. 12 × 1,200 = 14,400 kg. 3. 10%: 1.2 m^3; 30%: 3.6 m^3. 4. 14,400 ÷ 66,000 ≈ 0.22 kg. 5. Yes. The mass stays 14,400 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; a second filter and a dark cup usually give clearer water faster; 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 Ryugu 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. **JAXA, "Asteroid Explorer “Hayabusa2”."**
   global.jaxa.jp/projects/sas/hayabusa2
2. **JAXA, "Hayabusa2 Project."**
   hayabusa2.jaxa.jp/en
3. **NASA JPL Solar System Dynamics, "Small-Body Database Lookup: 162173 Ryugu (1999 JU3)."**
   ssd.jpl.nasa.gov/tools/sbdb_lookup.html#/?sstr=162173
4. **Wikipedia, "162173 Ryugu."**
   en.wikipedia.org/wiki/162173_Ryugu
5. **Wikipedia, "Hayabusa2."**
   en.wikipedia.org/wiki/Hayabusa2
6. **NASA NSSDCA, "Planetary Fact Sheet (orbit comparison)."**
   nssdc.gsfc.nasa.gov/planetary/factsheet
7. **NASA/JPL Solar System Dynamics, "JPL Small-Body Database (SBDB) API record."**
   ssd-api.jpl.nasa.gov/sbdb.api?sstr=162173&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. Ryugu Outpost Kit, Sample edition, by Outpost Kits (10timesIt LLC) · ryugu.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.