

Moon Dome Habitat

Teacher Guide · Grade 3

Hearts Invention Lab STEM Curriculum · Reverse Engineering Series · Simple systems and forces



The Moon Dome Habitat, a low dome on the grey lunar surface

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How to use this guide

This guide has the Grade 3 unit. Each unit has 4 or 5 lessons. Students reverse-engineer the Moon Dome Habitat: they explode it into parts, read each part's job, rebuild it and name their own version. Each unit then adds a hands-on activity using household and classroom items only.

- **Digital-only.** This curriculum is sold as printable, downloadable files. No kits or materials packs exist or are needed.
- **Facts and sources.** Every research fact carries a source tag [S#]. A few parts have no published source yet; these are marked “design reasoning, no source” so students can see the difference between evidence and design ideas.
- **Practice values.** Some maths problems in grades 9–12 use clearly labelled practice values (PV). These are made-up numbers for the exercise, not source facts.
- **Standards.** NGSS and CCSS codes are given with paraphrased descriptions. Check them against your state's standards.
- **The app.** heartsinventionlab.com/app/ (Ages 5+). Open Reverse Engineer, then Moon Dome Habitat. Lumet, the guide, leads the teardown (Basic mode), the rebuild, naming your version and the material quiz (Advanced mode).

The Moon Dome at a glance

The Moon Dome is a low dome built mostly from moon dust (regolith), so very little has to be carried from Earth. It has a hard outer shell of sintered regolith blocks, shaped like an upside-down hanging chain (a catenary), and a soft inflatable liner inside that holds the air [S1, S3, S8]. In the app it comes apart in 5 layers, from the outside in:

1. Outside covering (radiation blanket, feed rover)
2. Outer shell (sintered blocks, hollow-cell wall, interlocking joints)
3. Floor and pads
4. Doors and window (airlock, self-cleaning seals, skylight)
5. Air liner



1. Sintered regolith blocks



2. Microwave-glazed floor and landing pad



3. Interlocking block joints



4. Hollow-cell shell wall



5. Moon-dust radiation blanket



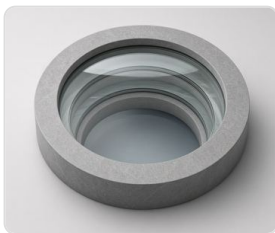
6. Inflatable air liner



7. Two-room airlock



8. Self-cleaning door seals



9. Small skylight window



10. Moon-dust feed rover

Grade-band progression

Band	Focus
K-2	Play and observation: parts, jobs, materials, taking apart and rebuilding
3-5	Simple systems and forces: arches, static electricity, energy, matter, measurement
6-8	Engineering design and data: criteria, constraints, controlled tests, fields and waves
9-12	Quantitative physics, chemistry, biology and engineering maths

Grade 3: Arches, Pushes and the Electric Broom

4 lessons · about 170 minutes in total · © 2026 Hearts Invention Lab

Overview

Third graders study two forces at work in the Moon Dome. The first is the squeeze in an arch: the blocks are only strong when pushed together. The second is the non-contact pull of static electricity, which is the idea behind the self-cleaning door seals. They test paper arches against flat beams and use a charged balloon to lift pepper off a plate.

Learning objectives

Students will:

- Show that an arch carries more load than a flat beam made of the same paper.
- Explain why moon bricks must be squeezed (compression), not stretched.
- Show that charged objects can push or pull without touching.
- Describe the job, material choice and build step of every Moon Dome part.

Standards alignment

Framework	Code	What students do (paraphrased)	Status
NGSS	3-PS2-1	Investigate the effects of balanced and unbalanced forces on an object's motion (paraphrased).	Aligned
NGSS	3-PS2-3	Ask questions to find cause-and-effect links in electric or magnetic interactions between objects not touching (paraphrased).	Aligned
NGSS	3-5-ETS1-3	Plan and carry out fair tests that control variables and find failure points (paraphrased).	Aligned
CCSS	3.MD.B.3	Draw scaled picture and bar graphs.	Aligned
CCSS	3.MD.A.2	Measure and estimate masses (grams, kilograms).	Suggested alignment
CCSS	RI.3.3	Describe the connection between steps in a technical procedure.	Aligned

"Aligned" means the unit directly addresses the performance expectation. "Suggested alignment" means a partial or supporting fit for the teacher to confirm.

Lessons and timing

Lesson 1: Explode and explore (45 min)

1. Take the Moon Dome apart in Basic mode. List the parts on a T-chart: made from moon dust / made from other materials.
2. Read the parts table (why material, what it does, how it's built).
3. Rebuild and name your version.

Lesson 2: Arch vs beam (hands-on) (45 min)

1. Build a flat paper beam and a paper arch between two book stacks.

2. Add coins one at a time until each fails. Record.
3. Graph the results.

Lesson 3: The electric broom (40 min)

1. Rub a balloon on hair or wool. Hold it above pepper on a plate.
2. Measure the height where pepper starts to jump.
3. Link it to the seal facts: moon dust can carry a charge, and electric fields can sweep it [S14].

Lesson 4: Advanced quiz and share (40 min)

1. In Advanced mode, match each part to its material.
2. Write a three-sentence explanation of why the dome is curved.

Materials (household and classroom items only)

- Copy paper or index cards
- Two equal stacks of books
- Pennies or other identical coins
- Balloons
- Ground pepper and a paper plate
- Wool cloth (or hair)
- Rulers

Nothing in this unit needs a purchased kit.

Hands-on activity: Arch vs Flat Beam

1. Make two stacks of books 15 cm apart.
2. Lay a flat card across. Add coins to the centre one at a time. Record the number at collapse.
3. Now bend a same-size card into an arch, with its ends pushed against the books. Add coins again.
4. Repeat each test 3 times (fair test: same card, same gap, same coin place).
5. Graph and explain: the arch pushes its load out into the books, so the card is squeezed instead of bent.

In-app activity (Hearts Invention Lab app, Ages 5+)

Lumet, the app's guide, walks students through each step. The app is free to open at heartsinventionlab.com/app/.

1. Moon Dome Habitat: use the exploded view, then Basic mode (5 layers).
2. Rebuild and name your version.
3. Advanced mode: material quiz for all 10 parts. Record your first-try score.

Every part: why this material, what it does, how it is built

Part (material)	Why this material was chosen	What the part does	How it is assembled in real life
Sintered regolith blocks (Moon dust (regolith) baked hard)	Moon dust is already there, so nothing heavy is carried from Earth, and no glue is needed. Heat fuses the grains. [S11]	Builds the outer shell that blocks heat, cold and tiny space rocks.	A robot focuses sunlight on moon dust until the grains fuse, then adds the next thin layer on top. [S11]

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Not for resale.

Part (material)	Why this material was chosen	What the part does	How it is assembled in real life
Microwave-glazed floor and landing pad (Moon dust melted with microwaves)	Real moon dust has tiny bits of iron that heat up fast in microwaves. [S4]	A hard, dust-free floor and a landing pad so rocket blasts don't spray dust.	Microwaves heat the dust until the grains fuse into a glassy surface. [S4, S6]
Interlocking block joints (Sintered moon dust with bumps and slots)	The same baked moon dust is used, shaped with bumps and slots so nothing extra is needed to hold it. [S7]	Locks blocks together so they don't slide.	Researchers printed blocks with matching shapes and tested fitting them together as a modular set. [S7]
Hollow-cell shell wall (Printed moon dust with closed hollow cells)	Hollow cells use less material but keep the wall strong. [S3]	Makes the shell strong but lighter, like the inside of a bird's bone.	A printer builds the wall layer by layer, leaving closed hollow cells inside. [S3]
Moon-dust radiation blanket (Loose moon dust, piled or bagged)	Loose moon dust is everywhere on the Moon, and thick dust blocks space rays. [S10]	Extra covering that blocks radiation and keeps the temperature steady.	Moon dust is heaped or bagged over the shell. [S10]
Inflatable air liner (Layered fabric bladder)	Fabric can stretch and hold air. Hard bricks can't hold air without leaking. [S8]	Holds the breathable air inside.	The air liner is a layered fabric balloon. The hard shell is its armour. [S3, S8]
Two-room airlock (Aluminium alloy walls with fabric chambers)	Metal walls are stiff around the doors. Fabric rooms are light. (design choice in the invention file, no source)	Lets people go outside without losing the air.	Metal walls with doors and seals are joined by fabric rooms. One room catches dust. [S12]
Self-cleaning door seals (Seals with built-in electrodes)	Electrodes (tiny wires) can push charged dust away. [S14]	Stops jagged moon dust from ruining the door seals.	Electrodes are built into the seal surface. [S14]
Small skylight window (Fused silica (very pure glass))	Fused silica is very pure glass that handles big temperature changes. (design idea, no source)	Lets in light and a view.	Kept small and coverable, because every window is a weak spot in the shielding. (design idea, no source)
Moon-dust feed rover (Aluminium frame, hard-wearing scoops)	Aluminium is light. Tough scoops stand up to scratchy dust. (design idea, no source)	Scoops and sifts dust for the printer.	It sifts out big rocks so the printer gets even dust. (design idea, no source)

Tags in brackets [S#] point to the Sources list at the end of this guide. "No source" marks a design idea from the invention file that no published source backs up yet.

Real-world assembly sequence

No moon dome has been built yet. The bricks are being tested on Earth with simulated moon dust. [S1]

1. A rover scoops and sifts moon dust. *[design idea, no source]*
2. Focused sunlight bakes the dust into blocks, layer by layer. [S1]
3. The blocks have bumps and slots and are fitted together as a modular set. [S7]
4. The shell is printed in a curved, upside-down-chain shape with hollow cells. [S3]
5. A layered fabric liner holds the air; the shell is its armour. [S3, S8]
6. Loose dust is heaped or bagged over the shell. [S10]

7. Microwaves fuse a hard floor and landing pad. [S4, S6]
8. A two-room airlock with dust-sweeping seals is added. [S12, S14]

The source files do not say whether the air liner goes in before or after the shell is printed, so the order of those two steps is a design question for students, not a fact.

Vocabulary

Word	Meaning
Force	A push or a pull.
Compression	Being squeezed.
Tension	Being stretched or pulled.
Arch	A curved shape that carries weight by pushing outward and down.
Static electricity	Electric charge that builds up on a surface.
Regolith	Moon dust and broken rock.

Teacher's background (cited facts)

F3 and F10 connect the arch test to real design. F17 links the balloon to the seals. Make clear that the balloon is only a model: real seals use electrodes, not balloons.

- Outer-shell blocks are made by heating regolith (moon dust) to about 1,000 °C with concentrated sunlight until the grains fuse. No glue or binder is shipped from Earth. [S1]
- The printed bricks had a strength similar to gypsum, so they work best in compression (stacked and arched), not when stretched. [S1, S2]
- The EU RegoLight project designed and tested interlocking, sunlight-sintered blocks as a modular set of parts, printed with a mobile print head and a sunlight focal spot no smaller than about 14 mm. [S7]
- A catenary shape keeps the shell in compression (squeezed, not stretched), which suits a brittle material. [S3, S8, S9]
- Moon dust is jagged and can carry an electric charge. A moving (travelling) electric field from electrodes in a surface lifts and sweeps it away. NASA has patented self-cleaning seals for hatches and airlocks that work this way. [S14]

Discussion questions

- Why are moon bricks good in an arch but poor as a flat beam?
- How is a charged balloon like the self-cleaning seal? How is it different?
- What variables did you keep the same in the arch test?
- Which part would you change in your version, and why?

Assessment

- Which held more coins: the arch or the flat beam? Why?
- Why must moon bricks be used in compression?
- What force lifts the pepper?
- Name one part not made from moon dust and say why its material was chosen.

1. Usually the arch, because the load squeezes it (compression) instead of bending it.
2. Their strength is similar to gypsum, so they are good when squeezed but weak when stretched [S1].
3. Static electricity, a non-contact electric force.
4. The air liner (fabric holds air without leaking) or the airlock (stiff metal walls for doors and seals); accept reasoned answers.

Rubric

Criterion	Beginning	Developing	Proficient	Extending
Fair test	No controls	Some controls	Controls named and kept	Suggests and tests an improvement
Force explanation	Missing	Names a force	Explains compression OR static	Explains both, using data
Parts knowledge	Fewer than 3 parts	3 to 5 parts	6 or more parts with jobs	All parts with material reasons

Differentiation and extension

- **Support:** Provide a data table template and sentence frames: “The [arch or beam] held more because [reason].”
- **Challenge:** Test a taller arch versus a flatter arch and graph the difference.
- **Extension:** Hang a string or chain between two fingers, sketch the curve, and flip the sketch. That is a catenary, the dome’s shape [S3].

Safety note

Pepper can sting the eyes: keep the balloon low and don’t blow on the plate. Watch for latex allergies and use a plastic comb instead if needed.

Sources

All facts in this guide come from the Hearts Invention Lab Moon Dome invention file and app data, which cite these sources (checked by web search on 2026-10-20):

- **[S1]** ESA, “Printing bricks from moondust using the Sun’s heat”. https://www.esa.int/Enabling_Support/Space_Engineering_Technology/Printing_bricks_from_moondust_using_the_Sun_s_heat
- **[S2]** ESA GSTP activity, “3D printing of a model building block for a lunar base outer shell”. https://www.esa.int/Enabling_Support/Space_Engineering_Technology/Shaping_the_Future/3D_printing_of_a_model_building_block_for_a_lunar_base_outer_shell
- **[S3]** ESA, “Building a lunar base with 3D printing”. https://www.esa.int/Enabling_Support/Space_Engineering_Technology/Building_a_lunar_base_with_3D_printing
- **[S4]** Taylor & Meek, “Microwave Sintering of Lunar Soil,” Journal of Aerospace Engineering 18(3), 2005. [https://doi.org/10.1061/\(asce\)0893-1321\(2005\)18:3\(188\)](https://doi.org/10.1061/(asce)0893-1321(2005)18:3(188))
- **[S5]** Shulman et al., NASA JPL preprint (2021), NTRS 20220008359. <https://ntrs.nasa.gov/citations/20220008359>
- **[S6]** Microwave sintering of lunar simulant, Scientific Reports (2021). <https://www.nature.com/articles/s41598-021-81691-w>
- **[S7]** Imhof et al., “Project RegoLight,” IAC-18.E5.1, 2018. https://liquifer.com/wp-content/uploads/2020/03/2018_Using_IAC-18E516x477461.pdf
- **[S8]** Wired, ESA and Foster + Partners moon base. <https://www.wired.com/story/foster-esa-moon-base-3d-printing/>
- **[S9]** Benvenuti, Ceccanti & De Kestelier, “Living on the Moon: Topological Optimization of a 3D-Printed Lunar Shelter,” Nexus Network Journal (2013). <https://doi.org/10.1007/s00004-013-0155-7>
- **[S10]** (Content unverified: page blocks automated reading; not re-read) Akisheva & Gourinat, “Utilisation of Moon Regolith for Radiation Protection and Thermal Insulation in Permanent Lunar Habitats,” Applied Sciences 11(9):3853, 2021. <https://www.mdpi.com/2076-3417/11/9/3853>
- **[S11]** Grande et al., “Protecting Crew and Surface Systems with a Long-Duration Lunar Safe Haven,” AIAA ASCEND 2021. <https://ntrs.nasa.gov/citations/20210022066>
- **[S12]** NASA NTRS, “Dual-Compartment Inflatable Suitlock”. <https://ntrs.nasa.gov/citations/20130013815>
- **[S13]** NASA EVA Office, “EVA Airlocks and Alternative Ingress/Egress Methods”. https://www.nasa.gov/wp-content/uploads/2017/02/2018-eva_airlocks_and_alternate_ingresseggress_methods_document.pdf
- **[S14]** NASA Technology Transfer, “Self-Cleaning Seals” (KSC-TOPS-101). <https://technology.nasa.gov/patent/KSC-TOPS-101>

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