

Flying Submarine

Teacher Guide · Grade 3

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



A small winged research drone skimming above the sea

© 2026 Hearts Invention Lab. App for ages 5 and up, and grown-up inventors too. Digital-only curriculum for printing and download. Licensed to the buyer only. Not for resale or public posting.

How to use this guide

This guide has the Grade 3 unit. Each unit has 4 or 5 lessons. Students reverse-engineer the Flying Submarine: 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#]. Parts or claims with no published source are marked “design reasoning, no source” (or “design idea, 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 Flying Submarine. Lumet, the app's crystal guide, leads the teardown (Basic mode), the rebuild, naming your version and the material quiz (Advanced mode).
- **License.** Licensed to the buyer only. Not for resale or public posting. A Family & Classroom License covers one home or one classroom; a School Site License covers every teacher at one school building.

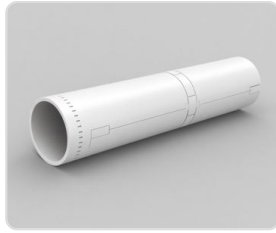
The Flying Submarine at a glance

The Flying Submarine is a small research drone that flies to a reef, lands on the water, then dives to check how healthy the ocean is. It carries **science tools only**. It borrows from real test vehicles: a drone that uses the same propellers in air and water and sinks by taking in water [S3], and Navy research that merges flying and underwater drones [S2, S4]. Several parts (body tube, seals, sonar, battery) have no published source yet and are marked as design reasoning. In the app it comes apart in 5 layers:

1. Outside (nose window, fold-in wings, splashdown nose and keel)
2. Body (main body tube, seals and O-rings)
3. Movers (ducted fans, ballast system)
4. Sensors and science (sonar and depth sensor, science pod)
5. Power (battery pack)



1. Nose window



2. Main body tube



3. Fold-in wings



4. Ducted fans



5. Ballast system



6. Splashdown nose and keel



7. Seals and O-rings



8. Sonar and depth sensor



9. Battery pack



10. Science pod

Grade-band progression

Band	Focus
K-2	Floating and sinking, windows and light, waterproof materials, taking apart and rebuilding
3-5	Ballast and balanced forces, sound waves and echoes, air vs water
6-8	Density and buoyancy design tests, monitoring ocean health, energy budgets
9-12	Buoyancy maths, ceramics and batteries, ocean ecosystems and bio-inspiration, pressure, sonar and design review

Grade 3: Ballast and Balanced Forces

4 lessons · about 165 minutes in total · © 2026 Hearts Invention Lab

Overview

Third graders investigate the ballast system. A real test drone sinks when it takes in about 100 ml of water [S3]. Students build a medicine-syringe or bottle ‘Cartesian diver’ sub, change one thing at a time, and explain sinking and floating as balanced and unbalanced forces.

Learning objectives

Students will:

- Plan a fair test of how added water changes floating.
- Describe floating as balanced up and down forces.
- Explain how the ballast system dives and surfaces.
- Record data in a table.

Standards alignment

Framework	Code	What students do (paraphrased)	Status
NGSS	3-PS2-1	Plan an investigation of balanced and unbalanced forces on an object’s motion (paraphrased).	Aligned
NGSS	3-PS2-2	Make observations to predict future motion from patterns (paraphrased).	Suggested alignment
NGSS	3-5-ETS1-3	Plan fair tests to find failure points (paraphrased).	Aligned
CCSS	3.MD.A.2	Measure liquid volumes in litres and millilitres.	Aligned
CCSS	3.MD.B.3	Draw scaled bar graphs.	Aligned
CCSS	W.3.7	Do short research projects.	Suggested alignment

“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: Explore the movers (40 min)

1. Take apart Movers; read the ballast card.

Lesson 2: Bottle sub (hands-on) (45 min)

1. See hands-on; record ml added.

Lesson 3: Forces diagram (40 min)

1. Draw arrows: weight down, water push up. When are they equal?

Lesson 4: Compare with the real drone (40 min)

Hearts Invention Lab is a 501(c)(3) non-profit organization. This work is licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License. Free to download and print for your own home or classroom. Not for resale.

1. About 150 ml cylinder; about 100 ml to sink [S3]. How did ours compare?
2. Rebuild and name your version.

Materials (household and classroom items only)

- Small plastic bottle with lid
- Measuring jug or medicine cup (ml)
- Tub of water
- Paper clips or coins (for balance)

Nothing in this unit needs a purchased kit.

Hands-on activity: How Much Water to Dive?

1. Float a capped, empty small bottle in the tub.
2. Add 10 ml of water at a time; cap and test after each.
3. Record the volume when it first sinks.
4. Pour out 10 ml at a time until it floats again.
5. Link it: the real drone takes in about 100 ml to sink and pushes it out to rise [S3].

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

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

1. Open Reverse Engineer, then Flying Submarine.
2. Explode the drone; read every part card.
3. Basic mode: take it apart by layer and rebuild it; name your version.
4. Advanced mode: match each part to its material.

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
Nose window (ALON, a clear ceramic)	ALON is very hard and clear, like a window that can't scratch easily. [S1]	Lets the camera see out while holding back water.	Only the nose window is ALON, because it is heavy and costly. [S1]
Main body tube (Carbon-fibre composite)	Carbon fibre is light enough to fly and strong enough to dive. (design idea, no source)	A sealed home for batteries and electronics.	Built as a tube and sealed; every gram is planned. (design idea, no source)
Fold-in wings (Carbon-fibre skin over foam)	Carbon-fibre skin over foam is light and stiff. (design idea, no source)	Give lift in air, tuck in underwater.	Hinged so they fold flat for swimming. (design idea, no source)
Ducted fans (Fibre-reinforced plastic blades in a ring)	One set of fans for both air and water saves weight. [S3]	Push it along in air and water.	Fans sit inside a ring that guards the blades. [S3]
Ballast system (Water cylinder, piston, pump and valve)	A cylinder, piston, pump and valve move water in and out. [S3]	Lets in water to sink, pushes it out to rise.	On one real drone, about 100 ml of water in is enough to sink it. [S3]

Part (material)	Why this material was chosen	What the part does	How it is assembled in real life
Splashdown nose and keel (Tough polycarbonate, foam crush layer)	Polycarbonate is tough; foam squashes. [S4]	Takes the bump of landing on water.	Engineers used computer flow tests to plan for landing forces. [S4]
Seals and O-rings (Rubber O-rings, magnetic couplings)	Rubber O-rings squeeze into gaps. (design idea, no source)	Keep water out where shafts and hatches pass through.	Magnetic couplings turn parts through a solid wall, so there is no hole. (design idea, no source)
Sonar and depth sensor (Piezo ceramic sonar, silicon pressure sensor)	Sonar listens for echoes; pressure tells depth. (design idea, no source)	Finds depth and obstacles where GPS can't reach.	Sonar at the front; pressure sensor open to the water. (design idea, no source)
Battery pack (Lithium-ion cells in a sealed case)	Lithium-ion stores lots of energy for its weight. (design idea, no source)	Powers flying and swimming.	Sealed case; plan: fly fast, swim long. (design idea, no source)
Science pod (Clear acrylic window, water sensors)	Clear acrylic lets sensors and camera see. [S5]	Carries a camera and water-health sensors.	Air-and-water drones have been proposed for tracking oil spills. [S5]

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

This drone is a design idea. Real test drones that fly and swim have been built, and this design borrows from them. [S2, S3]

1. Build the carbon-fibre body tube. *[design reasoning, no source]*
2. Seal in the battery and electronics. *[design reasoning, no source]*
3. Fit O-rings at the joints and hatches. *[design reasoning, no source]*
4. Install the ballast cylinder, piston, pump and valve. [S3]
5. Mount the ducted fans. [S3]
6. Fit the ALON nose window and the splashdown nose. [S1, S4]
7. Hinge on the fold-in wings. *[design reasoning, no source]*
8. Add sonar, depth sensor and science pod. [S5]

The source files do not give a build order. Sealing the electronics before adding movers and wings is design reasoning; students may propose a different order.

Vocabulary

Word	Meaning
Ballast	Weight added or removed to control sinking.
Balanced forces	Forces that cancel.
Buoyancy	The upward push of water.
Millilitre (ml)	A small unit of liquid volume.
Piston	A part that slides inside a cylinder to push.

Teacher's background (cited facts)

F4 is the anchor fact. Buoyancy is the water's push up; weight is gravity's pull down.

- That drone sinks and rises with a small ballast cylinder of about 150 ml, with a piston, a pump and a valve. Taking in about 100 ml is enough to sink it. [S3]
- One real test drone uses the very same propellers in the air and underwater, instead of carrying two sets. [S3]

Discussion questions

1. How many ml made your bottle sink?
2. Why does adding water make it sink?
3. How does the drone get the water out?
4. What made our test fair?

Assessment

1. When does an object float?
2. How much water sinks the real test drone?
3. How does the drone rise?
4. Show your data table.

Answer key

1. When the water's push up balances its weight.
2. About 100 ml [S3].
3. Its pump pushes the water out.
4. Accept complete table.

Rubric

Criterion	Not yet	Getting there	Got it!
Fair test	Many changes	Mostly fair	One variable
Forces	None	Names a force	Explains balance
Data	Missing	Table	Table and graph

Differentiation and extension

- **Support:** Pre-marked bottles at 10 ml steps.
- **Challenge:** Use a bigger bottle: predict the water needed before testing.
- **Extension:** Read about how fish or submarines rise and sink, and cite where you read it.

Safety note

Supervise near water; wipe spills.

Sources

All facts in this guide come from the Hearts Invention Lab Flying Submarine invention file and app data. Each source below was checked on 2026-10-20 by fetching the page or matching the DOI's title (notes in brackets):

- **[S1]** Hartnett, Maguire & Gentilman, "Aluminum Oxynitride Spinel (ALON): A New Optical and Multimode Window Material," Ceramic Engineering and Science Proceedings (DOI title matched). <https://doi.org/10.1002/9780470318140.ch6>
- **[S2]** U.S. Navy fact file, "Flying-Swimmer (Flimmer) UAV/UUV" (page text checked). <https://www.navy.mil/Resources/Fact-Files/Display-FactFiles/Article/2160517/flying-swimmer-flimmer-uavuuv/>
- **[S3]** Alzu'bi et al., "Loon Copter: Implementation of a hybrid unmanned aquatic-aerial quadcopter with active buoyancy control," Journal of Field Robotics, 2018 (full text checked). <https://doi.org/10.1002/rob.21777>
- **[S4]** Geder et al., "Development of an Unmanned Hybrid Vehicle Using Artificial Pectoral Fins," Marine Technology Society Journal 51(5), 2017 (DOI title matched). <https://doi.org/10.4031/mts.j.51.5.4>
- **[S5]** Rutgers University news, "Navy funds Rutgers to develop drone equally adept at flying and swimming," 23 October 2015 (page text checked). <https://www.rutgers.edu/news/navy-funds-rutgers-develop-drone-equally-adept-flying-and-swimming>
- **[S6]** Defense One, "This Duck-Like Drone Could Spy on Enemy Subs," March 2015, quoting D. Edwards (NRL), "Flimmer: A Flying Submarine," NRL Spectra, 2014 (page text checked). <https://www.defenseone.com/technology/2015/03/duck-drone-could-spy-enemy-subs/108811/>

© 2026 Hearts Invention Lab. All rights reserved. Original curriculum content. Real research appears only as cited facts. Licensed to the buyer only. Not for resale or public posting. Use is covered by the purchaser's license (Family & Classroom License or School Site License).