DIVE! DIVE!
THE HISTORY AND TECHNOLOGY OF SUBMARINES

A curriculum guide for 5th grade

Developed by the Education Department of the National Museum of the United States Navy
Washington Navy Yard, D.C.
www.history.navy.mil
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Teachers,

Thank you for choosing to use the DIVE! DIVE! educational program from the U.S. Navy Museum’s Field Trip in a Box collection as part of your curriculum. Valuable information can be gained from visiting museums and participating in their activities, but sometimes it is not possible to visit the actual museum site. In those instances we have decided to bring the museum to you!

Dive! Dive! is a program designed for 5th graders to learn the history and some of the technology behind submarines. Throughout this lesson students will:

- Learn what makes a ship float
- Why submarines can float and sink
- How submarine technology has changed over the past 200 years
- Key improvements to submarine design, and the people who made them

Officially, submarines have been a part of the U.S Navy since 1900, and there have been many different types and classes of submarines. This lesson focuses upon three specific submarines for their historical significance and technological advancement, Turtle, Hunley and Holland, and more broadly talk about diesel and nuclear submarines (with specific subs used as examples.) The modern Navy has several different classes of submarines, and if there is a specific boat or class that especially interests you or your class, please feel free to discuss them. More information on all of the currently deployed submarines can be found at www.navy.mil. Also, for more indepth information about historic submarines please visit the Naval History and Heritage Command’s website, www.history.navy.mil.

All the parts of the lesson are designed to introduce your students to the concepts of buoyancy, density and history of submarines. If constrained by time, the main lesson is DIVE! DIVE! (activity 2) and can be done on its own. We highly encourage doing the Does it Sink or Float? prior to DIVE! DIVE! so your students can have a hands on look at how a submarine operates. The additional activities are optional, but included to give your students a more in depth look at the concepts, and can be used in centers, science projects or as optional homework assignments.

Materials included in your kit:

- Teacher’s curriculum guide
- Photo cards for Activities 2-3
- Modeling Clay
- Plastic Basin
- Plastic container with lid
- Drinking straws
- Pipettes
DIVE! DIVE! TEACHERS WELCOME

- Hex nuts
- Signal Flag memory deck
- 5x7 Signal Flag cards
- Activity Sheets

Items you will need to provide:
- Collection of things composed of various materials to test for floating
- Empty soda can
- 16 oz water bottles with lids (one per student)
- Scissors
- Masking tape
- Permanent marker
- Buckets or cups for water (or you may use the plastic basin)
- Markers/colored pencils
- LEGOS

We hope you enjoy this experience and that your students enjoy learning about the U.S. Navy!

-The U.S. Navy Museum Education Department
Before the students begin exploring the history of submarines, they must first understand what makes a submarine unique from regular surface ships. In this activity they will learn how things float, and what submarines must overcome to dive.

**Background information for instructor:**

**Why do objects either sink or float?**

An object sinks or floats depending on its density in comparison to the density of the liquid it is in. If an object is placed in water, and it is denser than the water, it will sink (negative buoyancy); if it is less dense it will float (positive buoyancy).

**What is density?**

Density is the degree of compactness of a substance (how packed together the atoms of an element are). To determine density, one calculates the Mass/Volume. That is why different objects of the same mass of weight can have differing densities. For example, 100 lbs of feathers will have a much lower density than 100lbs of bricks (the feathers take up more space than bricks).

**What is buoyancy?**

Buoyancy is the upward force on an object that is produced by the surrounding liquid in which it is fully or partially immersed due to the pressure difference of the fluid between the top and bottom of the object.

When an object is immersed in water, its bulk pushes some water aside (displacement). The water pushes back exerting a force called upward buoyancy force, or upthrust. When the net upthrust is equal to the amount of fluid displaced by the object, it will float. If the mass of an object and subsequent density is more than the resulting upthrust, it will sink.

**Then why can a ship float?**

A ship stays afloat because its weight is equal to that of the water it displaces. The material of the ship itself may be heavier than water (*per volume*), but it forms only the outer layer. Inside it is air, which is negligible in weight, but it *does* add to the volume. (Remember Density= Mass/Volume) The mass of the ship (plus contents) *as a whole* has to be divided by the volume *below the waterline*. If the ship floats, then that is equal to the density of water (1 kg/l). If weight is added to the ship, the volume below the waterline will have to increase too, to keep the mass/weight balance equal, so the ship sinks a little to compensate.
What will sink and what will float?

Sink: If the object is more dense than water, it will overcome the upthrust (water pushing back on the object), and sink.

Float: The displaced water from the less dense object equals the waters upthrust, keeping it from sinking.

Wood (Floats)

Aircraft Carrier (Steel + Air = less dense than water) (Floats)

Surface/float: Reduce Mass (Add air to tanks)

Submerge/sink: Add Mass (Add water to tanks)

Submarines can change densities

Steel (Sinks)
Activity: Sink or Float? (To be done in a small group)

Materials Needed:

- Collection of things composed of various materials to test for floating (i.e. pencils, erasers, keys, marbles, cork, sponge, coins etc)
- Modeling clay
- Plastic container with lid
- Empty soda can
- Flexible Straws
- Plastic Basin
- Activity Sheet

Activity #1

1. Arrange collected objects in front of the plastic basin filled water.
2. Have students guess which ones will float before you put them in water.
3. Record predictions on Activity Sheet.
4. Place objects in water and record results.
5. Give each student modeling clay, and have them make different shapes like balls, tubes, and triangles. Have them record their predictions and results on the Activity Sheet.
6. Have the students try shaping the clay like a boat, or soda cap (flat bottomed with sides). Have them record the results.

Activity #2

1. Place the uncovered plastic container in the water, discuss why it sunk (It filled with water).
2. Remove the container, dry it and replace the lid. Ask the students what they think will happen when they put it in the water. Test the container, and discuss why it floated (The air trapped inside makes it float).
3. Ask the students to predict if a soda can will float. Now discuss what can be done to the can to make it sink. Sink the can, and discuss why there are bubbles coming out of the can.
4. Now ask the students to think about what would happen if they could put the air back in the can. (The air will push out the water and it will float).
5. Give a straw to each student (or elect one student to do the experiment). Have the student insert the straw into the opening of the can, and blow air into it. Discuss the results.
**Activity 1**

Name: ____________________________________________________________

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<tr>
<th>Object</th>
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Why do you think some of the objects floated, and others sunk? Did changing the shape of the clay help it to float? Why or why not?

_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
Activity 2

Name: _______________________________________________________

You already know that if you put a brick into water, it sinks, or a rubber ducky floats on top of the bath water. But, why do they float or sink?

Why do you think a brick sinks in water? ______________________________________

Why do you think a rubber ducky floats? ______________________________________

Weight is one reason why rocks sink, but we need to learn about **density**.

**Density** is the amount of weight in a certain amount of space. Objects can have the same weight, but different **densities**.

For example:

10 pounds of bricks have a higher density than 10 pounds of rubber duckies. (the bricks take up a smaller space than the ducks)

Water has density too, only a certain amount of water **molecules** can fit into a space, like a cup. When you put the rubber ducky into the water, the water actually pushes back against the ducky, and it floats because it is **less dense** than the water. The water pushes back against the brick when you put it into the water, but since it is **denser** than the water, it sinks.
DIVE! DIVE! DOES IT SINK OR FLOAT?

But what about ships? Ships are heavy, why don’t they sink?

Why do you think ships float?
________________________________________________________________________
________________________________________________________________________

Do the first two steps of Activity 2

When you trapped air inside the container, it floated! This helps to show how a ship floats. Air trapped inside changes the density of the entire ship. Even though a ship may be made from heavy material, the total density of the ship and the air inside, is less than that of the water, so it is able to float.

Now, let’s talk submarines!

Do parts 3-5 on Activity 2.

Why did the can sink when placed in the water?
________________________________________________________________________
________________________________________________________________________

Why did it float when you blew air into the can?
________________________________________________________________________

The can is like a submarine. If filled with water, it becomes denser than the water, and it will sink. If you push out the water and replace it with air, it will float. It is very important for submarines to be able to change its density. Why do you think it is important?

Submarines must be able to change their density in order to surface and to dive. If they were unable to, they would be stuck!
Now that your students have discovered how ships float and submarines dive, it is now time to take a closer look at their history. All bulleted questions are optional questions for your students to help them to think about the topic and allow them to voice their opinions on the subject.

To begin, ask the students introductory questions:

- How old will the U.S. Navy be this year? (A: 233+ years old. The U.S. Navy celebrates its birthday as October 13, 1775.)
- Do you think that submarines look the same as they did 200 years ago? Why or why not?

Underwater exploration has fascinated people for thousands of years, yet submarine travel did not become common until the mid-twentieth century. The ancient Athenians used divers in secret military operations, and a legend maintains that Alexander the Great descended into the sea in a primitive diving bell. Many talented and curious people dabbled with submersible boat designs, but achieved limited success. It was not until 1900 when the U.S. Navy commissioned its first submarine. 

**Turtle 1776**

Pre discussion questions:

- What material(s) do you think *Turtle* was made out of?
- Do you think *Turtle* was fast or slow?
- What do you think life was like on *Turtle*?
- How do you think it moved through the water?
- What kind of weapons do you think were on board?
- How did the driver of *Turtle* communicate?

The first American submarine was designed before the Revolutionary War by David Bushnell, a young inventor from Connecticut. He designed and built a one-man submersible vessel that he called *Turtle*. Bushnell’s *Turtle* featured a hand-cranked screw-like oar that moved the boat forward and back underwater, air pipes that brought fresh air into the boat (only on the surface), and a primitive torpedo to attack enemy ships. The submersible embodied four basic requirements for a successful military submarine: the ability to (1) submerge, (2) to maneuver under water, (3) to maintain an adequate air supply to support the operator of the craft, and (4) to carry out effective offensive action against an enemy surface ship.

**Building Materials**

*Turtle* was constructed from two wooden shells covered with tar and reinforced with steel bands. Lighting was a problem for *Turtle*.

- Why couldn’t Bushnell have candles burning inside *Turtle*?
Six small pieces of thick glass in the top were the only source of natural light. After Bushnell pondered the problem of lighting the inside of the ship and after learning that using a candle would hasten the use of the limited oxygen supply of the air inside, he solicited the help of Benjamin Franklin who cleverly hit upon the idea of using bioluminescent foxfire to provide illumination for the compass and depth meter.

To provide stability and negative buoyancy, *Turtle* carried 200 pounds of lead in the bottom of the submarine.

**Movement**
- Do you think *Turtle* had ballast tanks?

*Turtle* did not have ballast tanks like submarines do today. Bushnell would fill a tank at the bottom of the submarine to submerge and a hand pump to resurface. It was propelled vertically and horizontally by hand-cranked screw propellers.

**Life on Board**
*Turtle* was not designed for a person to stay onboard for very long. When submerged, it only had about 30 minutes of air for the operator of the submarine. The only time spent onboard was to complete the mission, which was to attack, and sink a British warship.

**Weapons**
*Turtle* only had one weapon on board, a "torpedo" which was an egg-shaped casing filled with 150 pounds of gunpowder and fitted with a rudimentary clock-work detonator. The operator would submerge under the intended target, and attach the explosives to the underside of the ship. After a delay of about 1 hour, the detonator would go off and explode the charge.

**Communications**
Once the hatch was sealed, the operator of *Turtle* did not have any means of communicating with the outside world. When *Turtle* returned to shore, the operator trusted his land based team to spot him and haul him ashore.
**Turtle’s mission**

Early in the War of Independence, Bushnell was encouraged by George Washington, Thomas Jefferson and Ben Franklin to adapt his invention for use in the fight against the British. He invented a waterproof time bomb which could be carried underwater and attached to an enemy ship by *Turtle*. Once the mine was connected to the target, a clockwork fuse (timer) allowed one-hour for pilot and craft to escape before the explosion.

It looked like confidence placed in Bushnell by Washington and other would pay off at New York in 1776. Scores of British fighting ships had lined the harbor and rivers surrounding Manhattan and Staten Island for months, choking off supply lines into the city. The ships were a perfect target for *Turtle* and its underwater mine.

The flagship of the British navy in America, HMS *Eagle*, was chosen as the target and *Turtle* was readied for combat. Just days before the planned attack the only trained pilot, Bushnell’s brother, fell ill. A last-minute substitute, Sergeant Ezra Lee, was brought in for intensive training on the series of levers, valves, cranks and pumps that powered the boat. He had only one week’s time to be ready.

Late in the evening of 6 September, a crew towed *Turtle* to a spot as close to the British fleet as they dared and turned it loose. Undetected but still visible on the surface, Lee rowed the boat around for about two hours until the time and tide were exactly right. As he drew closer and closer to Eagle, Lee heard the voices of the sailors on deck through his open hatch. Silently, he sneaked *Turtle* under the stern of his target. It was just before dawn. The time was right to plant the explosives and depart unseen. Lee closed the hatch and prepared to submerge.

Controlled by Lee’s newly-acquired knowledge of pumps, valves and levers, *Turtle* sank deeper and deeper, and then rose beneath her target. Lee began the job of attaching the explosive mine to the flagship, but long minutes of drilling into the hull had no effect! A second try was also a failure. He may have been drilling into a thick copper hull-coating, some barnacles or just a hard place in the wood, but he couldn’t break into the hull. Then he lost control of the submarine! It popped to the surface within sight of the *Eagle’s* crew. Fortunately, Lee flooded the ballast tanks in time to remain undetected. In his report about the incident, he said he “sunk like a porpoise.”

Despite all his efforts, Lee had to abandon his mission. Daybreak meant an increased chance of discovery by the British. He retreated as fast as he could, submerging (to avoid detection) and surfacing (to see where he was going) over and over again. His unsteady, zigzag route caught the attention of the British who sent out a rowboat and crew to investigate. Lee released his exploding mine in their direction and watched as they retreated in confusion. Later, the mine went off right next to *Eagle* (the original target), shooting a fountain of water to an incredible height. The British were so scared by the
mysterious happenings of the morning that they cut their anchor cables and sailed downstream to get away!

*Turtle* made several other unsuccessful attacks on British warships. The boat was lost when the sailboat on which she was transported was attacked and sunk by the enemy in the Hudson River.

**Discussion questions:**

- Why do you think the British sailors were scared of *Turtle*? Would you be scared?
- Although Turtle’s mission was a failure, in what ways was it a successful submarine?
- How would you have changed the design of Turtle to make it more efficient for its mission?

**CSS Hunley 1864**

As naval surface ships continued to develop throughout the nineteenth century, submarines were still considered experimental and unsafe for the U.S. Navy. However, during the Civil War, both Union and Confederate forces experimented with submarines. One such experiment was H.L. *Hunley* named for its financier Horace L. Hunley.

**Building Materials**

*Hunley* was made from parts of an iron boiler held together with iron strips and rivets. There were two ballast tanks with sea cocks (plugs) to the water outside the ship. To submerge, the sailors unplugged the sea cocks to fill with water. To surface the Sailors had to hand pump the water out of the submarine. The only light was from a single candle burning next to the depth gauge. There were two hatches on the top with viewing windows and an “air-box” a system to allow fresh air to come into the submarine when it was at the surface. When completely submerged, *Hunley* had enough air to support the crew for two hours.

**Movement**

*Hunley* relied on the strength of her crew of eight men to move her through the water. Seven of the men turned the hand cranked propeller, and one steered. Each end of
Hunley was equipped with ballast tanks that could be flooded and pumped out by hand pumps. Iron weights were bolted to the underside of the hull to add extra ballast. If Hunley needed to surface quickly, the iron weights could be detached. Like submarines today, Hunley had two horizontal “dive planes” that could be adjusted to change the submarines underwater position and depth.

**Life on Board**
The inside of Hunley was very small, the men could not even stand up straight inside! The men crouched (rather than sat, as they had to bend over due to the curve of the submarine) along a wooden bench as they cranked the propeller shaft. There was very little air to breathe, and the only light came from a single candle from the fore part of the submarine. The men would have to crank the propeller shaft for hours through the darkness to achieve a speed of 3 knots (3.5 mph). Food was scarce, only what the men could put in their pockets or under the bench (which was wet with sea water), and the only bathroom facilities was a bucket shared among the men.

**Weapons**
The first two (unsuccessful) missions of Hunley used a towed torpedo, a bomb that was towed, and designed to be dragged by a line behind the submarine. The Hunley would dive under the target vessel, while towing the torpedo on the surface towards it. Once the torpedo made contact with the hull of an enemy ship, it would then explode sinking the ship. However the threat to Hunley was just as great as the enemy ships due to heavy seas throwing the torpedo around, so ultimately during its third and final mission, it used a spar torpedo. This torpedo was designed to be rammed into the hull of an enemy ship. It was fastened to the end of the 17 foot spar and fitted with a barb on its end. The idea was to ram the spar torpedo into a target and then back away, causing the torpedo to detach from the spar. A line from the torpedo to the submarine would spool out as the sub reversed its course. Once the submarine was at a safe distance, the line would detonate the warhead.

**Communications**
Allegedly, after the crew’s mission was completed, Hunley was to surface, and shine a blue lantern to signal men on shore. Those waiting on shore, lit bonfires to lead the crew home.

**Hunley’s mission**
After the outbreak of the Civil War, President Abraham Lincoln issued an order for the Union forces to begin to blockade all major Southern ports.

- What do you think happened to the Confederate’s supplies and ability to receive supplies after this order was signed?

Since Charleston, South Carolina held the largest port, and was the location of Fort Sumter (a strategic hold for the Southern forces), the harbor quickly became the main focus of the Union blockade. The question began to arise, “can a secret submersible save
Charleston harbor from the increasing Union blockade?” The commanders of the Confederate forces thought that it could be a key weapon against the Union, therefore Hunley was transported by train from its trial runs in Mobile, Alabama to Charleston and arrived on August 12, 1863.

The first mission ended in disaster. On August 29, an eight man crew was assembled and was sent out to attack a Union ship. Before the submarine could complete its mission, Hunley sunk off the end of Fort Johnson wharf. Four of the crew survived and was able to tell their superiors that the officer in charge accidentally stepped on the lever that controlled the dive planes (which controls the movement of the submarine), which caused the submarine to dive while her hatches were still open.

Hunley was quickly salvaged from the bottom of the harbor, and refit for a new mission. On October 15, 1863, crewed with men from Mobile, who had performed the training missions, went out for another attempt to attack the Union blockade. Again the mission ended in tragedy. Hunley’s ballast tanks were overfilled and sunk to the bottom of the harbor.

- With two crews lost, should the Confederate Navy continue to try and use Hunley against the Union Blockade? Why or why not?

Even though Hunley had sunk twice, killing 12 men, the necessity of keeping Charleston harbor free from the blockade overshadowed any fear the last crew may have felt.

On February 17, 1864 Hunley set out on its third and final mission. The new crew of Hunley sailed four miles off Breach Inlet, in Sullivan’s Island just outside Charleston Harbor. Her target was the USS Housatonic, the Union Navy’s largest ship in the harbor. As the crew of Hunley slowly made their way towards the ship, a look out on USS Housatonic spotted what he thought was a porpoise, until he realized it wasn’t an animal, and rang out the alarm. The crew attempted to fire upon Hunely, but the cannons could not reach the low target in the water, and the bullets from the rifles bounced right off Hunley’s hull. Just as Hunley reached her target, the crew cranked the propeller as hard as they could, racing the submarine towards the ship at 3 knots (3.5 mph). Finally, the men on Hunley rammed the long metal spar into the stern of the ship, and planted the 135 pound torpedo into the side of the ship. The men on Hunley immediately sent the submarine into reverse, towing their detonation rope behind them. Once the torpedo was detonated, the explosion caused USS Housatonic to sink in about three minutes. (This is the first time a submarine sunk an enemy ship). Five sailors on board Housatonic were killed, but for the crew of Hunley, the outcome was much more tragic. After signaling their success to their look outs on shore, Hunley and her entire crew vanished into the sea.

Discussion questions:
- Historians are still trying to figure out what happened to the ship, what do you think happened?
- Do you think that Hunley was a success or failure?
Why do you think the U.S. Navy continued to research submarine technology?
What would you add to Hunley to improve it?
Do you think life on board Hunley was better or worse than on Turtle?

USS Holland 1900
Ten years after the end of the Civil War, Irish-born John Holland began designing and building submarines in the United States. Holland submitted his first submarine design to the U.S. Navy in 1875, which at the time was dismissed as impractical. Seeing this rejection as a challenge, Holland quickly went back to the drawing board to redesign and improve on the construction of these underwater boats. By 1888, the U.S. Navy recognized the potential for submarines in its fleet and held a design competition for a new underwater vessel. Holland won the competition and began building the submarine Plunger five years later. After experiencing difficulties with Plunger, Holland began work on another submarine that he named Holland IV. For his sixth submarine, Holland introduced a new method of propulsion using a gasoline engine. He designed a small, lightweight gasoline engine that turned a propeller while the boat cruised on the surface. The engine ran a generator, a machine that produces electricity, to charge batteries necessary to run an electric motor during underwater operations. Holland’s efforts proved successful and he was able to persuade the U.S. Navy in April of 1900 to purchase this submarine. It was added to the fleet as USS Holland (SS-1) six months later.

Building Materials
USS Holland structure and ballast tanks were built from steel, a material much stronger than iron, so it was able to withstand greater water pressure as well as provide better protection from weapons. The turret (conning-tower) was made of bronze, and the access hatch was sealed with a rubber gasket. Three viewing windows allowed the operator to steer the submarine with the hatch closed. Additionally, USS Holland was built with two masts, which allowed the Navy Board of Inspection access to observe the movements of the submarine while it was submerged.
Movement
USS *Holland* was equipped with a 45 horsepower gasoline engine giving it a top speed of 8 knots (9.2 mph). Since gasoline engines give off exhaust, and take in needed oxygen for the crew, the gasoline engine was only used on the surface, when the hatch could be kept open. In addition to running the submarine when on the surface, it could also recharge the batteries while underway. When the submarine was submerged, it used its 50 horsepower Electro-Dynamic Dynamotor (electric engine). *Holland* had three ballast tanks, the first submarine to do so, as it gave the submarine more stability when diving. The tanks also incorporated the new technology of compressed air to expel the water from the tanks when surfacing, getting rid of the need to hand pump the water out.

Life on Board
Life on board was still very difficult for Holland’s 7 crewmembers. The 53 foot long, 10 foot wide submarine was not designed for extended stay, as there were no berthing (sleeping) or messing (eating) areas for the crew. The longest recorded mission was two and a half days, and the crew ate from picnic baskets and slept on newspapers on the battery deck. The largest advancement was the quality of the air supply. When surfaced, a fan inside the submarine helped the carbon dioxide rich air escape, and fresh air to fill the submarine. When submerged, they had plenty of air for their short dives, and they had a system in place to add more air if needed. Should their air supply run out while submerged, the crew could let in some of the compressed air used for the ballast and weapons systems to blow out the “bad” air and circulate fresh air in. This system was not used, as they did not submerge long enough to need it.

Weapons
USS Holland had three weapons systems on board: the aerial torpedo, dynamite gun and whitehead torpedo. Little is known about the aerial torpedo, as it was never used, and eventually removed during modifications. The dynamite gun, was a pneumatic weapon (fired by pressurized air) fired a 222 lb projectile in a range of 1000 yards on the surface and 30 yards submerged. This weapon also was not utilized during its service in the U.S. Navy. The weapon system that was used was the whitehead torpedoes. This torpedo was 11 feet long and had a range of 800 yards at 26.5 knots (35 mph).

Communications
USS *Holland* was not designed for outside communication (however they could use light signals if needed, like *Hunley*), but during trials, a surface ship was always near to give messages and record information coming from the submarine.

**USS Holland’s mission**
USS Holland was primarily used as a training vessel, training cadets at the U.S. Naval Academy in Annapolis, MD. She also conducted training runs and torpedo tests, to help the Navy improve its submarine service.
Diesel Submarines

Although the gasoline engine worked well on paper, the engine had flaws. Gasoline is highly flammable and unstable. Using this fuel in a confined environment, such as the submarine, endangered the crew as there were fire risks and exhaust fumes. Another danger were the batteries that ran the electric motor during underwater travel. They were heavy, bulky, terribly inefficient, and potentially explosive. Finding a safer means of propulsion was needed if the submarine was ever to submerge for long periods of time.

Around the same time Holland was creating his submarines, German scientist Rudolf Diesel developed an excellent substitute for the gasoline engine. Diesel’s engine used a fuel that was more stable than gasoline and could be stored safely. The engine also did not need an electric spark to ignite the fuel, adding another element of safety. These advantages, plus improved fuel economy, granted submarines with Diesel’s engines longer and safer cruises on the surface. While underwater, batteries were still necessary to provide power. After 1909, Diesel engines would be used in American submarines for nearly 50 years.

**While there were several classes of submarines during WWII, in this section we will focus on one, the Balao class, and looking at USS Pampanito (SS-383).**
DIVE! DIVE! HISTORY OF U.S. SUBMARINES

Building Materials

Balao class submarines, like the USS Pampanito were constructed from 7/8 inch high tensile steel, which gave the subs an increased diving depth of 100 feet over their predecessors, the Gato class, a greatly kept secret of the war.

- Why do you think it was important for the Navy to keep the depth capabilities a secret?

Movement

USS Pampanito had 4 diesel engines on board which turned 4 main generators. The power created from the generators ran the electric motors on board and charged the batteries. The submarine always ran on electric power, as the diesel engines were not connected to the propellers. When the submarine was surfaced, it drew its power from the generators (because they could run the engines), when submerged it ran on battery power.

When traveling on the surface, USS Pampanito travels like a surface ship, except for the flood ports that are open to the sea below. Water can’t fill the outer hull because the trapped air prevents any water from entering, therefore the submarine maintains positive buoyancy. If the submarine wants to dive, the main vent can be opened, and sea water fills the ballast tanks until the desired level of neutral buoyancy is achieved.

Life on Board

Even as technology improved, life on board a diesel submarine was hot, cramped and dangerous. The 312 foot ship held 80 men who lived and worked together 70 days at a time. Water was an invaluable resource, and the men on board had to ration it carefully. Drinking, cooking and maintaining the engine components took priority, so things like showers and laundry often were given up. Men on board submarines were allowed to
grow beards (with the approval of their Captain), something not allowed on surfaced ships, because of the limited water supply. A veteran of diesel subs remembers storing onions in the showers, since it was not going to be used for anything else! Air was also a limited resource. While the submarine carried several thousand pounds of compressed air onboard, that air was used for the weapons, engines and ballast systems. Breathable air was trapped inside the submarine, and as it slowly turned to carbon-dioxide rich air, the submarine was forced to surface to open the hatches. This was often dangerous, especially if they were in enemy territory! There were also not enough beds (bunks) on board for every man. Therefore, the enlisted men (and junior officers) would have to “hot bunk,” or while you were working, someone was sleeping in your bed! Eating was done in shifts, just like all the other jobs on board.

Weapons
Diesel submarines had several different weapons on board. These included torpedoes, a main deck gun, anti-aircraft guns and hand held weapons. Torpedoes are the main weapon, which are forced out of the torpedo tubes by compressed air, once in the water however they self propel themselves towards the target (unlike shells that use the force from the gun). During WWII, the deck guns and anti aircraft guns protected the submarine from enemy aircraft and ships when they surfaced for air or reconnaissance. If the submarine ever boarded another ship, or was boarded, they could use their hand held weapons to defend themselves.

Weapons on board diesel submarines were also much more accurate than before. This was due to the instillation of RADAR (radio detection and ranging) and SONAR (sound navigation and ranging) during WWII. Each submarine’s conning tower had a RADAR antenna, which sent out radio waves to determine the distance away a surface ship was in relation to the sub. Additionally, submarines had SONAR, to track objects under the water. First to be developed was passive SONAR. Passive SONAR picks up sounds using electronic listening equipment. A target can be detected by the noise it makes from its machinery, the propeller, or the sound of the water passing around the vessel as it travels.

- Besides other ships and submarines, what types of things would you hear in the ocean?
Later in the war a second type of SONAR was developed. Active SONAR produces and emits a burst of sound or a “ping.” This is reflected back when it hits an object and is registered as a “blip” on a screen. Active SONAR sends and receives sound transmissions. This method is more dangerous, since an enemy’s SONAR could detect the ping.

- What animals use active SONAR (echo-location) to find food?

**Communications**

Diesel submarines had significantly more means of communication than all of the previous boats. Each submarine was equipped with several radios, set to different frequencies, to receive Morse code and voice messages. They also had radios to send messages back.

**Nuclear Submarines 1955 to present**

Despite the success of diesel-powered submarines, the quest for a single power source continued. The concept of nuclear power was discovered by German scientists in the 1930s. Upon learning of this idea, American physicist Ross Gunn visualized the potential for nuclear-powered submarines and Phillip Abelson first sketched an image of one. The most recognized proponent of nuclear-powered submarines in the U.S. Navy was Admiral Hyman G. Rickover.

Rickover managed a research team that converted the concepts of nuclear power into working submarines. Nuclear power uses atoms, the smallest particles of an element, to produce an enormous amount of energy. That energy allows the power plant on submarines to super heat water and thus creating steam. The steam then powers a giant turbine which turns the sub’s propeller. Those small nuclear power plants on submarines could supply the necessary power for these boats to travel up to 500,000 miles and to stay underwater almost indefinitely without refueling.
Rickover convinced the Navy and the Atomic Energy Commission that nuclear power was the ideal propulsion method for submarines. On January 17, 1955, the first nuclear-powered submarine, USS *Nautilus* went to sea. On her first voyage, Nautilus traveled completely submerged in the Atlantic for more than 1,300 miles. In 1958, she traveled under the polar ice cap and reached the North Pole.

**USS Norfolk**

**Building Materials**
Both the pressure hull and superstructure are built from steel. A large difference between the diesel submarines and nuclear, is that nuclear subs do not have a deck. Diesel submarines have decks, like ships, that held their large guns. Since nuclear submarines do not need to surface to take in fresh air, there is no longer a need for anti aircraft protection.

**Movement**
The 360 foot *Norfolk* is propelled by one nuclear reactor. The speed and maneuverability of a submarine depends upon its class, or what it was built for. Fast attack submarines, (like *Norfolk*) are the fastest and can reach speeds of anywhere between 20 and 30 knots (23-35 mph), but the true number is classified. The larger submarines, Ballistic Missile submarines, which carry long range missiles, are slightly slower at 20 knots (23 mph).

Dive planes, which act like airplane wings, allow the boat to ascend or descend several hundred feet per minute. The planes were moved from the sail (conning tower) of the submarine to the bow of the submarine increasing stability and maneuverability.

**Life on Board**
Life on board a nuclear submarine is much better than it ever has been, but that doesn’t mean it isn’t hard! Submarines still have the smallest areas (in the Navy) to live in, some of the most technical systems, like the reactor and dive systems, and they still have to worry about air!

Of the three basic things submariners need, food, water and air, two of those they are able to make themselves. Submarines today have the capacity to make between 10,000 and 40,000 gallons of fresh water every day to support the cooling system, and to support the men inside (for eating, drinking, washing, etc). They accomplish this through a distillation system. Salt water from the ocean is heated to boiling, and once the steam is cooled, fresh water is left behind. Fresh air is also produced on board for the sailors. Air laden with carbon dioxide is pushed through a scrubber system that filters out the gas. Separate oxygen tanks and oxygen producing systems monitor the levels of oxygen in the air and automatically release oxygen into the submarine if needed. Of the three basic needs, food is the only thing that the sailors can not produce on their own. Today’s submarines have very large freezers and refrigerators and take many of the same foods.
that you eat: pasta, hamburgers, pizza, really anything that the cook wants to make! On the smaller submarines, space is still an issue, so often times when a sub is fully stocked, can foods line the walkways, and planks of wood are placed on top of them for the men to walk on.

Sleeping is still much like diesel submarines, they share their bunks with another, but they do get a small gear locker to keep their personal items.

When a submariner is off duty, there are many things that can keep him busy. DVD and TVs in the mess areas, work out equipment in the engine room, and catching up with family through limited internet access.

**Weapons**

Fast attack submarines like *Norfolk* carry both MK48 torpedoes and Tomahawk cruise missiles. The Mark 48 torpedo is only used in submarines, and it is a much more sophisticated weapon, than those used on diesel submarines. The weapon has a five mile range that is controlled by on board sonar, and digital guidance and control system. If a torpedo went off course, the sailors have the ability to download a new course to the weapon after it has been launched. The Tomahawk cruise missiles are for targets on land or in the air. The 19 foot missile has a range of 1,000 miles, and with it’s on board GPS systems it is extremely accurate. The precision of these two weapons enable the submariners to fight an enemy without damage to surrounding communities or people. The larger ballistic missile submarines also carry Trident I and Trident II ballistic missiles. These 34 and 44 foot missiles have a range of 4,000 miles, and like its smaller counterparts, it is highly precise. By having long range weapons on board, it allows for our submariners to protect themselves and their country without putting their ship directly in harm’s way.

**Communications**

Nuclear submarines communicate and sense other ships with radio, RADAR, SONAR. They now also have the ability to use telephone and internet due to the improvement of satellite communication.

**Scientific Exploration**

Not all submarines in the U.S. Navy are for deterring aggression and protecting the United States. The Navy has had and still has several submarines dedicated to research the world’s oceans.

- What kinds of things would you research in the ocean?
- Why do you need to research those things?

One large obstacle that submariners needed to overcome in order to research the deep areas of the ocean was the increasing water pressure as they descended further. When we
stand at the beach, one atmosphere (14.7 pounds per square inch or psi) of pressure is pressing down on our bodies. Our bodies compensate by pushing out the same amount of force. Since water is heavier than water, the pressure increases the farther down in the water you travel. Every 33 feet, one more atmosphere is added to the pressure. For humans, we can support 3-4 atmospheres before it is harmful, so about 99-132 feet deep. Submarines were designed to protect us from the pressure, but they too have their limits. Modern nuclear submarines have a maximum operating depth of about 1600 feet and a crush depth, of about 2400 feet.

That isn’t really far when you think about it, the ocean is over 35,000 feet deep! Think about all of the plants and animals that live below where our defense submarines can go!

That is where deep submergence vehicles (DSV) come in. They are designed differently, to withstand the great pressure changes of the ocean. Not all deep submergence vehicles are built to go all the way to the bottom of the ocean. *Trieste*, which we will look at here, is capable of making the descent. Other research submarines may only be designed to go halfway, depending on the purpose of the submarine.

**Trieste 1960**

**Building Materials**

Trieste was built in Italy by a Swiss scientist, Auguste Picard. Comprised of steel, it had two distinct sections to the submarine. The largest was its gasoline and water ballast tanks. This gave Trieste its buoyancy, and allowed her to freely dive independent of any ship or cable. The second chamber or pressure sphere housed the two operators and equipment. To create a sphere capable of withstanding the pressure of the bottom of the ocean, the builders made the walls of the sphere 5 inches thick. This caused a problem, since the sphere weighed 28,660 lbs or over 14 tons, and the resulting density was so great, it would sink. However by attaching the float chamber filled with gasoline (which is less dense than water) on top, it compensated for the dense sphere and made it buoyant.

**Movement**

*Trieste* had very limited maneuverability, other than sinking and small side to side movements. Its main objective was to reach the bottom of the ocean, and be able to come back up. To sink, it could fill
its water ballast chamber, and if needed release some of the gasoline from the main tank. To achieve positive buoyancy, the pellets in the two hoppers would be released, as like traditional submarines, the pressure was too great for compressed air to blow out the salt water.

**Life on Board**
*Trieste* was not designed for a long term stay. Its two operators were in the submarine for 9 hours, the time it took to descend and ascend from the bottom of the ocean. The sphere was a chilly 45 degrees F. The air was filtered by scrubbers, much like the other submarines. The two pilots snacked on chocolate bars during their journey as they did not have much room for anything else!

**Weapons**
*Trieste* did not have any weapons on board.

**Communications**
The submarine had a sonar/hydrophone on board that they could use to communicate with the surface ship.

**Trieste's mission**
On January 23, 1960, *Trieste* made history by reaching the bottom of the Challenger Deep in the Mariana Trench. It took nearly 5 hours to descend the 35,797 feet. Once there, Jacques Piccard and Lt. Don Walsh spent 20 minutes investigating the bottom. They saw several types of small fish and a substance covering the ground made up of plankton and other microscopic animals. This was a huge discovery, as it was not know if vertebrate life (those with skeletons) could live at such extreme pressures. After their 3 hour ascent, no other manned craft has ever returned.

**Discussion questions:**
- Besides animal life, what other things can you study in the ocean?
- Why is important to study the ocean and its contents?
DIVE! DIVE! CARTESIAN DIVERS

Activity: Cartesian Divers

Materials Needed:

- 16 oz water bottle with lid
- Pipette
- Hex nut
- Scissors
- Masking tape
- Permanent marker
- Extra water in pitchers or sink
- Buckets or cups filled with water

1. Fill water bottles so they are ¾ full.
2. Slide hex nut onto pipette. It is a snug fit, so it will take a little effort to get the nut to slide all the way up to the bulb of the pipette.
3. Cut the pipette just below the nut (this is your submarine)
4. Have the students squeeze the pipettes in the buckets or cups to fill them partially with water. (They are filling their ballast tanks with some water)
5. Have them drop the pipette into the bucket or cup. The pipette should not sink, nor should it “bob” in the water. The top of the bulb should just barely break the surface of the water.
6. Once the pipette floats properly, remove it from the cup (making sure not to squeeze any water out) and put it in the filled water bottle, replace the cap, tightly!
7. The pipette should be floating in the bottle, as it did in the bucket.
8. Squeeze the sides of the water bottle.
9. If the pipette did not sink, there may be too little or too much water in the bottle, or too little water in the pipette.
10. Write your name on the masking tape and adhere it to the side of the bottle.

Discussion questions:

- Why do we need to fill the pipette with water at the beginning? Will it sink if it is empty to begin with? Why or why not?
- Why does the pipette sink? What is happening to the amount of water inside the pipette?
- Why does it float when you stop squeezing?
Background:

Before the advent of the telegraph, telephone or two-way radio, ships would communicate with a series of signal flags. Each flag represents a letter of the English alphabet and each has a specific meaning when flown alone.

This system of international maritime signal flags is still used today and is recognized by the International Maritime Organization, established by the United Nations.

While signaling is not used daily, it can be used when radio silence is required, (in a hostile environment), or when the radio is down. Today, signal flags are most often used as an alert system to other ships. Each flag represents a warning or message such as, “have a diver in the water” (“A” flag) or “I am disabled communicate with me (“F” flag). Please refer to the supplementary materials for the full meanings of each flag.

Along with a corresponding flag, each letter of the alphabet is represented by a word rather than a sound, which is called a phonetic alphabet.

A Phonetic Alphabet: is a list of words used to identify letters in a message transmitted by radio or telephone. Spoken words from an approved list are substituted for letters. For example, the word "Navy" would be "November Alpha Victor Yankee" when spelled in the phonetic alphabet. This practice helps to prevent confusion between similar sounding letters, such as "m" and "n", and to clarify communications that may be garbled during transmission.

Pose this question to your students:
If a man was on a boat and needed help, but his radio was broken and he is out of shouting distance, how could he communicate with the ship next to him?

Activities:

Name Writing (can be in centers/groups or full class)

Materials needed:

5x7 Signal Flags
Name Writing worksheet
Markers

1. Put the 5x7 flags in a pocket chart in alphabetical order. Have the students “write” their name by drawing the flags and writing their name out with the phonetic alphabet.
Sending a Message!

Materials needed:
5x7 Signal Flags
Sending a Message worksheet
Markers

1. Put the 5x7 flags in a pocket chart in alphabetical order. Draw the message on the bottom of the worksheet using flags.

Signal Flag Memory (centers/groups)

Materials needed:

Signal Flag memory deck

1. Shuffle deck
2. Lay each card face down on a table
3. On each turn, students get to turn over two cards. If they don’t match, they must turn them back over; if they match, they keep the cards.
4. The student with the most matches wins!
DIVE! DIVE! SIGNAL FLAGS!

Name Writing

Name: __________________________________________________________________

Instructions: Draw your name in signal flags on the flag poles! (Hint: the flags fly top to bottom) An example “L” is drawn in for you.

Now write your name with the phonetic alphabet! Example: Lima Alpha Uniform Romeo Alpha (LAURA)
Can you help these sailors send a message? Name:

Message: Ahoy There!
Can you help these sailors send a message? Name:
Can you help these sailors send a message? Name: Answer Key

Message: Ahoy There!
Underwater Vehicle Design

Materials needed:
- LEGO's
- Activity sheet

1. Divide your class into teams
2. Each team will be making one submarine according to the rules on the activity sheet.
3. Give the teams about 5-10 minutes to discuss what they want to include in their submarine.
4. Depending on how much time you have, give the students between 30 minutes and 45 minutes to complete their project.
5. Have each group choose a writer and presenter. The writer records the answers to the questions (that the group answers together) and the presenter will be showing off the product to the class by describing the submarine and answering the questions to the class.
6. A reward can be given to the team that best follows all of the requirements! (Bonus points for teamwork!)
Names: _______________________________________________

Mission: Each group will be required to design and build an underwater vehicle in a set amount of time. Your group will need to include all of the elements below when designing your underwater vehicle.

Defense    Habitability    Scientific Research    Movement

Directions:
1. Decide which person will work on what part of the submarine.

Defense: _____________________ Habitability: ________________

Scientific Research: ________________ Movement: ________________

2. Elect a presenter and a recorder. The presenter will be presenting your final project to the class. The recorder will be writing the answers to the questions (on the back) that your team has answered as a team.

Presenter: ______________________ Recorder: ______________________

3. Use the empty box below to create a rough drawing of what you would like your vehicle to look like. The drawing will be a guide to get you started on your project. Your group may not be able to design a vehicle exactly like the one you’ve drawn, but this is where you will need to think quickly and creatively to solve a problem!
4. When instructed to do so, you may empty your LEGO box onto your work area and start to build.
5. Use your time wisely! It may be a good idea to start answering your questions while you are building, the better you answer, the easier it will be for your presenter!

Questions:

1. **Defense:** There are many dangers lurking in the world’s oceans! Rockslides and volcanic eruptions happen in certain parts of the ocean. Sharks and other sea creatures might look at your submarine like a tasty treat. How will your submarine defend itself?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

2. **Habitability:** Your submariners will need to stay underwater for extended periods of time. What have you done to your vehicle to make them safe while they work? Are there any comforts from home to make their stay any easier?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

3. **Scientific Research:** It’s not all fun and games underwater! What is the mission (job) of your submarine? What are you studying while you are underwater? How does the vehicle you have designed help with that research?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

4. **Movement:** How does your submarine move through the water? How does it sink and surface?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Buoyancy
Build and Maneuver a Submarine

Materials Needed:
- Empty 16 oz plastic water or soda bottle with hole in cap (the hole should be big enough to pass a flexible straw through)
- Three wide rubber bands
- 24 pennies
- Aluminum foil
- Adhesive tape
- Flexible straw
- Large tub of water

Procedure:
1. Cut three holes in side of the water bottle.
2. Stack the pennies into three piles containing 4, 8 and 12 pennies.
3. Carefully wrap stacks of pennies with foil.
4. Place a rubber band around the plastic bottle and slide it next to the closest hole. Position the remaining rubber bands next to the remaining holes.
5. Place the four penny stack under the rubber band closest to the bottle’s top.
6. Place the eight penny stack under the middle rubber band, next to the middle hole.
7. Place the twelve penny stack under the last rubber band. (NOTE: The weights should be next to the holes, NOT over them)
8. Push the shorter end of the straw (about one inch) through the hole in the bottle’s cap. Reattach the bottle cap to the bottle. Keep the flex section outside and bent upwards. Tape straw securely into place in bottle cap.
9. Lower the submarine into the water. Do not let long end of straw take in water.
10. Observe the action of the sub and record your observations.
11. When the sub stops sinking, blow into the straw.
12. Observe the action of the sub and record your observations.

Discussion Questions:
- What makes the submarine sink?
- What makes it surface?
Habitability
Making Fresh Water: Distillation

**Background:** During long voyages underwater submarines must make their own water for drinking, cooking, bathing and laundry. Distilling equipment on board makes fresh water by boiling sea water and collecting the steam as it condenses on cooled surfaces. The condensed steam is fresh water.

**Objective:** Students distill fresh water from salt water to replicate the process done on submarines

**Materials Needed:**
- 1 heat source (stove or hot plate)
- 1 old tea kettle
- 1 metal spoon
- Water to fill kettle
- Salt
- Padded glove
- 1 clear drinking container

**Procedure:**
1. Fill kettle with water
2. Add lots of salt
3. Place the kettle on heat source. Turn it to high and boil water until steam begins to escape from the spout.
4. Place the metal spoon in front of the escaping steam.
5. Collect the water condensing on the metal by dripping it into the drinking container.

**Discussion questions:**
Collect about 1” of water in the glass and taste it.
1. Is it still salty?
2. What makes the freshwater separate from the salt?
3. What happens to the salt?
DIVE! DIVE! ADDITIONAL ACTIVITIES

Operation
Propulsion: Making a Screw-Style Propeller

Background: Submarines need a source of propulsion to move forward. David Bushnell, designer of Turtle, realized that a screw-like device when turned, could push his craft through the water. Modern propellers are similar to his early screw design, but the blades have a curves surface like an airfoil. They are shaped like wide, crescent-shaped knife blades that cut slowly but powerfully through the water. The broad blades push large amounts of water backwards producing a powerful reaction, as well as strong suction that causes the blade (and the boat) to be pulled forward.

The following activity, which shows how a propeller pushes water to provide forward thrust, uses puffed cereal instead of liquid.

Objective: Students construct, operate, and discuss the properties of a screw-style propeller.

Materials Needed:
- Lightweight cardboard
- 1 10” dowel
- 1 empty plastic 2 liter soda bottle with top and bottom cut out
- 1 pencil
- Electrician tape
- Scissors
- Puffed cereal in a large bowl
- 1 small bowl

Procedure
1. Trace 6 circles onto cardboard, using bottom of soda bottle as your pattern.
2. Use the end of dowel as a pattern to trace a small circle in the center of each big cardboard circle.
3. Cut out the big circles traced on the cardboard.
4. Cut out the small circles by cutting across to the center of the circle.
5. Stack the large circles.
6. To assemble your screw propeller, tape a cut edge of each big circle to the opposite edge of another circle stacked below it. Taping the opposite edges one below the other will produce a spiral.
7. Push the dowel through the center of the spiral.
8. Stretch the spiral along the dowel to form a screw pattern, tape the top and bottom ends of the spiral to the dowel.
9. Place the completed screw propeller into the cut soda bottle.
10. Fill a large bowl with puffed cereal and place on table. Position small bowl to catch cereal as it rises out of the soda bottle. A stack of books works well.
11. Lower screw propeller into the large bowl at a slant and turn the dowel.

Discussion Questions
1. What happens? Why?
### Operation

#### Detection: Submarine Tag

**Background:** A submarine operates “blind” in an environment full of unknowns. However, it must be able to locate approaching vessels and objects in its path. Submarines use a variety of devices to “see” and “hear” from under the sea. SONAR, the most effective, was developed during World War II. It serves not only as a detector of sounds but also as a means of protection for a sub and her crew. By removing the necessity of cruising at periscope depth (59 feet or less), a sub is able to maintain her invisibility and increase her safety.

In its active mode, SONAR emits a series of “pings” which can be heard and tracked by other vessels. Passive SONAR issues no sound but rather picks up those made in the surrounding sea. It is the SONAR system most used by the navies of the world today. An easy way to separate the two types is to think of “active SONAR” as a device that speaks and hears, and “passive SONAR” as one that only hears. Submarines also use SONAR to “see” much in the same way blind people rely on the sound to judge the position of the objects that surround them.

**Submarine Tag:** “Sink the Admiral” is an ancient game still played by children of the Eastern Mediterranean. It’s played in America as “Battleship.” This game of Submarine Tag, played in two rounds, explores both active and passive SONAR. It is similar to “Battleship” in many ways but involves detection rather than destruction.

**Objective:** Students understand the properties and difficulties of using active and passive SONAR.

**Materials Needed:**
- Blindfold

**Preparation:** Clear a large circle in the center of the room (or play outside). Pick one student to play the part of a DESTROYER. Choose 3 other students to be SUBMARINES. The object of the game is for “submarines” to avoid detection. Place the “destroyer” at the center of the circle and the “subs” around the edge. Blindfold the “destroyer.”

**Play (Round One):** Subs circle the destroyer at various speeds and depths. Destroyer makes SONAR sound (ping) as it points to edge of circle and turns slowly. Subs remain silent unless they receive a direct hit (finger point) from the destroyer, at which time they must “blip” in return, but can continue moving. Once original SONAR contact is made, destroyer leaves the center and moves toward the targeted circling sub while sending out more SONAR “pings.” (Blips must be returned). The round is over when the destroyer is close enough to locate the “submarine” by
DIVE! DIVE! ADDITIONAL ACTIVITIES

touching it. Submarine can change directions or “depth” in order to lose the destroyer.

Round Two: Play a few rounds of Submarine Tag in the passive SONAR mode. The game stays the same except there are no sounds emitted or returned. The blindfolded destroyer must simply listen and try to catch the moving subs as they circle.

Discussion Questions
Round one
1. How easy was it to locate a submarine?
2. What would have made it easier? Harder?

Round two
1. Which kind of SONAR made it easier to find the subs? Why?
After the completion of the program, DIVE! DIVE!, writing a friendly letter is a great way to reflect on the experience and tell us (the staff of the U.S. Navy Museum) what they liked best about the program.

Quotes from previous friendly letters (from the Hat’s Off Program):

“…my favorite hat was the helmet.” Troy, 2nd grade

“Dear Mrs. Hockensmith, Thank you for sending us Field Trip in a Box. My favorite part was trying on the hats.” David, 2nd grade

“Plus I also liked singing Anchor’s Aweigh.” Leena, 2nd grade

“It was fun to make the hats. I put three gold stripes to be commander.” Shelby, 2nd grade

We can’t wait to hear what your students have to say!
PHOTOS!

We are very interested in your class and their participation in DIVE! DIVE! We would appreciate it if you would share any photographs that you take of your students participating in the DIVE DIVE! program. After your students submit the completed photo release form, we will be able to use the photos in future promotion of the program, both in print form and on the web. If you are interested in sending photos, please include either the photograph or a CD of high resolution images. We look forward to seeing your class!

Mrs. Drake’s 2nd graders, Redlands, California
Photo Release Form

By signing this form, I allow the staff at the National Museum of the United States Navy to use any photo of my child taken during his/her participation in _________________ (name of program) in ________________ (name of teacher) ____ grade class. Uses will include, but are not limited to, advertisements in print and on the internet, for promotion of the Field Trip in a Box series.

Name of child:____________________________________________________________

Name of Parent/Guardian (please print):_______________________________________

Signature of Parent/Guardian:________________________________________________

date:____________

National Museum of the United States Navy
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www.history.navy.mil
SUPPLEMENTAL MATERIALS: SIGNAL FLAGS

What do those flags mean? When flown alone, each flag gives an important message! The international meaning is in parentheses.

A: I have a diver down; keep well clear at slow speed.
B: I am taking in, discharging, or carrying dangerous cargo.
C: "Yes" or "affirmative".
D: I am maneuvering with difficulty; keep clear.
E: I am directing my course to starboard.
F: I am disabled; communicate with me.
On aircraft carriers: Flight Operations underway
G: I require a pilot.
H: I have a pilot on board.
I: Coming alongside. (I am directing my course to port.)
J: I am on fire and have dangerous cargo; keep clear.
K: I wish to communicate with you.
L: You should stop your vessel immediately.
M: My vessel is stopped; making no way.
N: No or negative.
O: Man overboard.
P: All personnel return to ship; proceeding to sea (Inport).
Q: Boat recall; all boats return to ship. (Ship meets health regs; request clearance into port.)
R: Preparing to replenish (At sea). Ready duty ship (Inport). (None.)
S: Conducting flag hoist drill. (Moving astern.)
T: Do not pass ahead of me. (Keep clear; engaged in trawling.)
U: You are running into danger.
V: I require assistance.
W: I require medical assistance.
X: Stop carrying out your intentions and watch for my signals.
Y: Ship has visual communications duty. (I am dragging anchor.)
Z: I require a tug.
Does it Sink or Float?

**Science** NS.5-8.1 Science as Inquiry

**Science** NS.5-8.2 Physical Science

**DIVE! DIVE!**

**U.S History** NSS-USH.5-12.3 ERA 3: Revolution and the New Nation (1754-1820s)

**U.S History** NSS-USH.5-12.5 ERA 5: Civil War and Reconstruction (1850-1877)

**U.S. History** NSS-USH.5-12.7 ERA 7: The Emergence of Modern America (1890-1930)

**U.S. History** NSS-USH.5-12.8 ERA 8: The Great Depression and World War II (1929-1945)

**U.S. History** NSS-USH.5-12.9 ERA 9: Post War United States (1945 To Early 1970s)

**U.S. History** NSS-USH.9-12.10 Contemporary United States (1968-to the Present)

**Science** NS.5-8.1 Science as Inquiry

**Science** NS.5-8.2 Physical Science

**Science** NS.5-8.5 Science and Technology

**Science** NS.5-8.6 Personal and Social Perspectives

**Science** NS.5-8.7 History and Nature of Science

**Signal Flags**

**Language Arts** NL-ENG.K-12.4 Communication Skills

**Technology** NT.K-12.4 Technology Communication Tools

**Writing a friendly letter**

**Language Arts** NL-ENG.K-12.5 Communication Strategies
Teacher’s Name: ___________________________ Grade Level: ___________
Name of School: ___________________________ Location: ________________
Number of students participating in program: ___________

1. Which of the included activities did you participate? (Circle all that apply)
   All Activities              Does it Sink or Float?  DIVE! DIVE!
   Signal Flags   Additional Activities: ____________    Writing a Friendly Letter

2. How long did it take to complete the program?
   One Afternoon   One School Day   Multiple Afternoons   Multiple Full Days
   Other______________

3. How did you hear about the program?
   _______________________________________________________________________
   _______________________________________________________________________

4. Were the instructions clear and easy to follow? Y    N    why or why not?
   _______________________________________________________________________
   _______________________________________________________________________

5. Were the activities appropriate to your grade level? Y    N    why or why not?
   _______________________________________________________________________
   _______________________________________________________________________

6. Would you change anything about the program? Y    N   If yes, please explain:
   _______________________________________________________________________
   _______________________________________________________________________

7. Would you recommend this program to your colleagues? Why or why not?
   _______________________________________________________________________
   _______________________________________________________________________

8. Additional Comments:
   _______________________________________________________________________
   _______________________________________________________________________
   _______________________________________________________________________

   Thank you for your participation and feedback!
When you receive DIVE! DIVE! you will find the following in your kit:

- Teacher’s curriculum guide
- Photo cards for Activities 2-3
- Modeling Clay
- Plastic Basin
- Plastic container with lid
- Drinking straws
- Pipettes
- Hex nuts
- Signal Flag memory deck
- 5x7 Signal Flag cards
- Activity Sheets

All materials except for the materials to make Cartesian Divers, drinking straws and activity sheets must be returned within 2 weeks of the completion of the program. Please return to:

Education and Public Programs Department  
Attn: Laura Hockensmith  
U.S. Navy Museum  
805 Kidder Breese St. SE  
Washington, D.C. 20374