

# Nautical Archeology – Mapping Using Trilateration and Triangulation

By Laurie Lindstrom, Math Teacher

**Subject/Grade: High School Geometry**

**Duration: 3 class periods**

## Materials Needed:

*Per Class:*

- Colored tape: painters tape works well
- Artifacts: Toys, lanterns, engine parts, Halloween skulls or other items to simulate shipwreck artifacts

*Per Group (3-6 students per group)*

- Tape Measure
- Job assignment handout
- Data collection table
- Colored pencils
- Stopwatch

*Per Student:*

- Graph paper
- Straight edge
- Pencil
- Safety compass
- Calculators

## Room Arrangements:

**Day 1:** Tables/Desks arranged in Groups of 3 to 6 students

**Day 2:** **If this can be done in another room that is helpful as setup may take some time.** Tables are arranged against the wall and the floor is marked with the outline of the shipwreck with artifacts situated in boxes marked with tape on the floor. The midline of the ship is the baseline and is marked in one foot increments (see **Figure One**).

**Day 3:** Tables/Desks arranged in Groups of 3 to 6 students

## Lesson Overview

The students will apply their knowledge of triangles especially the Side-Side-Side Theorem to generate a map to scale of a simulated shipwreck. They will label the map describing parts of the ship with correct nautical terminology.

## Michigan Content Expectations:

### Michigan Geometry Content Expectations Addressed:

**Geometry and Measurement Content Standard 2:** Expectations 1, 2, 3, 5

**Geometry and Measurement Content Standard 3:** 1-6

**Michigan Physical Science Course Content Expectations Addressed:**

**Force and Motion P.FM:** Develop an understanding that the position and/or motion of an object is relative to a point of reference. Understand forces affect the motion and speed of an object and that the net force on an object is the total of all of the forces acting on it. Understand that the Earth pulls down on objects with a force called gravity. Develop an understanding that some forces are in direct contact with objects, while other forces are not in direct contact with objects.

**Focus Question:**

- How can we accurately map a wreck site without destroying the integrity of the wreck?
- Can this data be used as evidence to reconstruct the cause of the shipwreck?

**Learning Objectives:**

*After this lesson students will be able to:*

1. Identify parts of a ship
2. Collect data carefully and accurately
3. Use data to create a scale drawing of a historic site
4. Use geometry to locate the locus of artifacts
5. Students will discuss the importance of preservation of shipwrecks

**Advance Preparation**

**Day 1 & 3:** Make copies of handouts: rubric, vocabulary, diagram of ship and procedure.

**Day 2:** Before school: Use painter's tape or masking tape to outline the perimeter of the shipwreck, trace the baseline, and before class: place artifacts at various locations on the simulated site. Before class: Set out colored pencils or markers.

**Day 3:** Gather safety compasses, straight edges, calculators and graph paper.

## Nautical Vocabulary:

<b>After end of the ship</b>	Away from the end of the ship that heads into the lake.
<b>Anchor pulpit</b>	The platform that a sailor stands on when hoisting or retrieving the anchor.
<b>Artifact</b>	A portable object that has been modified, shaped or used by people in the past.
<b>Baseline</b>	The line that is used to measure the location or direction of artifacts or structure of ship.
<b>Bow</b>	The structure of the ship that is most forward and usually curved part of the ship.
<b>Datum Point</b>	Key reference points used to measure artifacts or large features.
<b>Deck planks</b>	Lumber that originated on the deck of the ship.
<b>Forecastle, Coaming or Aft Hatches</b>	Reinforcements and covers for going below deck or stowing cargo below deck.
<b>Forward end of the ship</b>	Towards the end of the ship that heads into the lake.
<b>Gaff</b>	A boat hook used as an aid in docking to grab lines or object that need to be retrieved overboard.
<b>Main Boom</b>	The large beams that provide structure perpendicular to the mid-line of the ship.
<b>Maritime Archeology</b>	A discipline that studies human interaction with the sea lakes and rivers through the study of vessels, shore side facilities, cargoes and human remains.
<b>Mooring Bits</b>	The cleats to attach ropes to when tying the ship to a dock.
<b>Port</b>	The left side of the ship as a passenger faces the forward end of the ship.
<b>Preservation</b>	The goal of protecting something from loss degradation or danger.
<b>Rudder and Rudder Post</b>	Usually large structure found at the stern of the ship for steerage.
<b>Sail Rigging</b>	The ropes used to hoist sails.
<b>Site Plan</b>	A detailed drawing of a collection of artifacts and or features left by people who once lived or worked in a specific place.
<b>Starboard</b>	The right hand side of the ship as a passenger faces forward.
<b>Stern</b>	Towards the end of the ship that is in the back of the direction of travel.
<b>Transom</b>	The structure of the ship that is at the stern of the ship.
<b>Triangulation</b>	Applying the ASA theorem to create a survey of a site. The angles along the baseline and the distance between the Datum are recorded. This data is recorded on a scale drawing with a protractor and straight edge to create a site plan of a shipwreck.
<b>Trilateration</b>	Applying the SSS theorem to create a survey of a site. The measurement along the Baseline and the distance from the Datum (two points on the

baseline) to the artifact. This data is recorded on a scale drawing with a straight edge and compass to create a site plan of shipwreck.

### **Windlass**

Shaft to wind sail rigging on. Also used to wind anchor chain or rope.

## **Background:**

Maritime Archeology is an exciting combination of mathematics, forensics sciences and art to attempt to reconstruct pictures of events in the past based on differing pieces of evidence. The mathematics used to create the site plan or survey is based on a hand out titled "Measuring Using Trilateration," GLHS/MAST Nautical Archeology Training Workshop. This technique uses the Geometry Theorem, SSS to map a shipwreck site. This lesson goes beyond that technique expecting students to also use Geometry Theorem ASA to create a site plan.

In any branch of science the ability to reproduce a data set will be reinforced by the careful attention to detail that is required by the lesson.

Both techniques attempt to record the site characteristics without disturbing the artifacts or integrity of the site. The ASA technique also is an attempt to propose a method which could be used by ROV, Remotely Operated Vehicles which my Geometry class has built this fall. Tom Farnquist of the Great Lakes Shipwreck Historical Society described the problems with Datum location with an ROV. ROV's can not use Global Positioning Systems below the lakes so they use three transponders set in fixed locations on the bottoms around the site. He again emphasized the importance of not disrupting the wrecks. Many wrecks are memorials to those lost in the Great Lakes and the desire to not desecrate or disturb the sailors final resting place is as important as maintaining the integrity of the historical site. Archeology uses computer simulations based on data and simple geometry and physics to calculate and hypothesize many scenarios of shipwrecks that have been mysteries for years. With hundreds of shipwrecks still lost and not located, archeologists now have new technology to try and locate and solve the mysteries of the disappearance of these ships.

In 2012, the French government is going to send research vessels to the Great Lakes to try and locate two World War II Mine-sweeping ships that vanished after being built in the United States. The mission will be a multi-national effort with France, Canada and the United States collaborating to sweep the bottom of Lake Superior for these large iron vessels. The latest status of this mission will emphasize the relevance of this activity for the students.

## **Procedure**

### **Day 1**

Students who are used to working in groups should be able to meet these goals with out much assistance. If they need help give them one goal at a time and make sure they complete each goal before moving on to the next.

Handouts: "Group Goals," "Vocabulary" and "Mock Shipwreck"

**Group Goals: Each group is assigned a number**

- 1. Job Assignments (if groups are smaller the Reel diver and Protractor diver can share responsibilities)**

- a. **Zero Diver:** The diver that holds the zero end of the tape measure.
- b. **Reel Diver:** The diver that holds the end of the tape that is measured from Datum to artifact.
- c. **Protractor Diver:** The diver that measures angle from Datum to artifact.
- d. **Recorder Diver:** Records data collected by other divers.
- e. **Sketch Artist Diver:** Sketches and records attributes of artifacts: ie. Condition, color, orientation. Overall sketch of the site.
- f. **Dive Master:** Records bottom time (8 minutes at this depth), making sure that all divers are safe and not experiencing symptoms of narcolepsy, fatigue, and making sure that they do not get tangled in the wreck.

**2. Label the diagram of the mock shipwreck provided to become familiar with terminology.**

All students are responsible for this assignment.

**Day 2**

Handouts: “Data Sheet”, “Dive Plan”, “Group Goals Day Two” waterproof paper (not really) for Sketch artist.

1. (Optional) Have “Giligan's Island Theme Song” or “The Wreck of the Edmund Fitzgerald” playing in the back ground when they come in.
2. Groups are to meet at their tables until the “Captain” (teacher) comes to get them.
3. There are five groups in my class and I will roll a die to determine which group goes first. If they pass inspection they will be allowed on the site.

Inspection Criteria:

- a. Each diver understands their roll
- b. They know the safe bottom time
- c. All handouts and tools are ready and understood.
4. Dive Group: Collects data on the wreck for their assigned time.
5. Captain inspects the site to ensure that the wreck site was not disturbed. (-5 points if found)

**Day 3**

Handouts: Graph Paper, safety compasses, straight edges, and directions handout.

When the group comes back to table or room, they are to look at the artist's sketch and see if there are any modifications or additions to be made. The sketch of artifacts should be colored and numbered.

**Assessment of Student Learning: Each Days' activity has a point value associated with it.**

**Extension:** Once the picture is complete they will have the information required to create a forensic description to with their interpretation of how each artifact came to rest in its location on the bottom of the great lakes. This will require concepts of force and motion that will be integrated from Physical Science.

A field trip to Whitefish Point to discuss their studies here with Mr. Farnquist, and a discussion of the French project to find the minesweepers would be an excellent followup.

**References**

**Chambers, Charlotte. 1997. *Hello Out There: All About Maps*. New York, New York: Franklin Watts/Grolier Publishing,, P. 32.**

**Martin, Dean. 1988.** “Guidelines on Acceptable Standards in Underwater Archeology,” The Scottish Maritime Studies Development Association, St. Andrews, Scotland.

**Thompson, Kate. 2010.** “Mock Shipwreck: An exercise in Maritime Archeology,” NOAA's National Marine Sanctuary Program <http://sanctuaries.noaa.gov/education/>

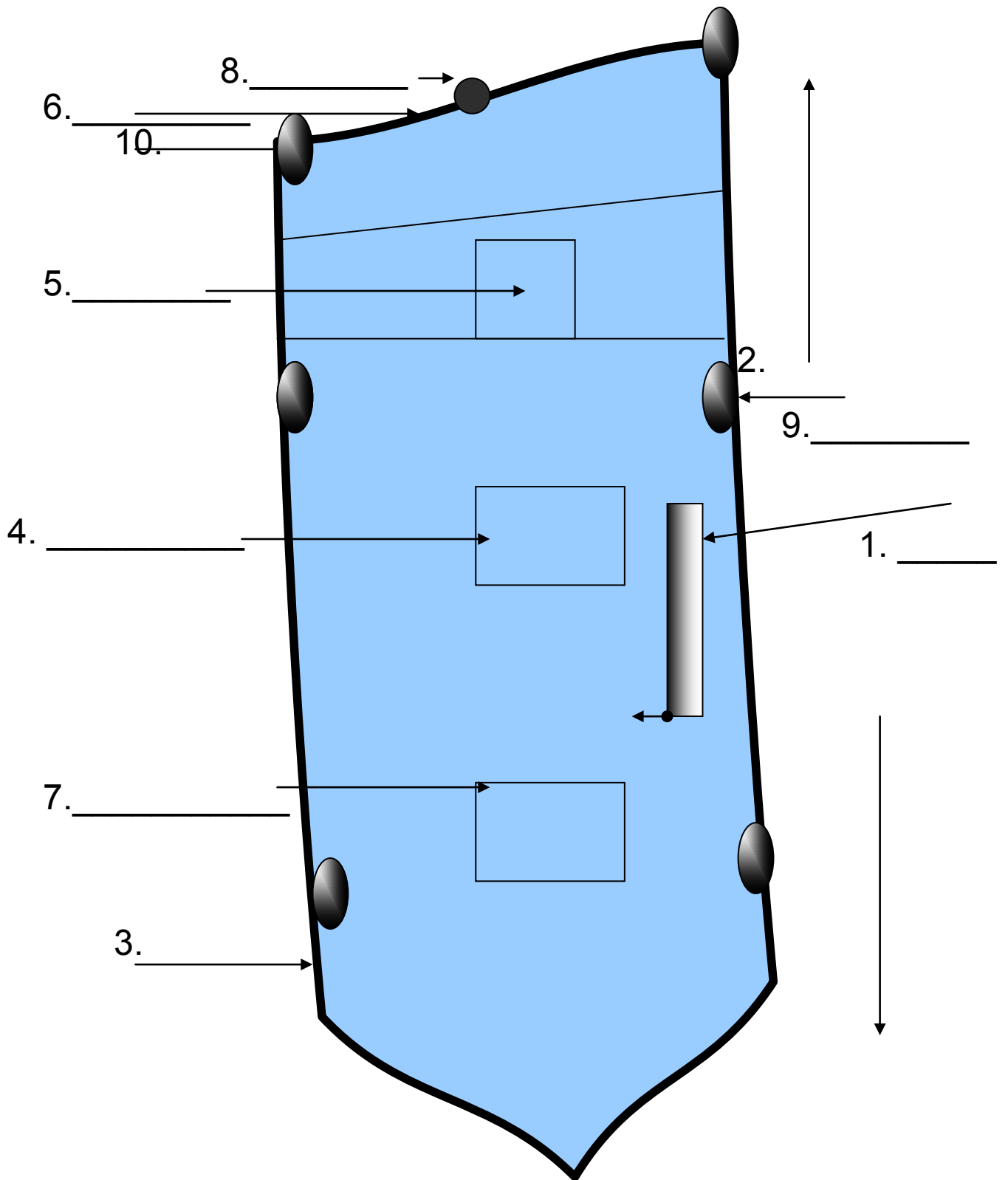
**Tannenbaum, Beulah and Myra Stillman. 1957.** *Understanding Maps: Charting the Land, Sea and Sky.* New York, New York: McGraw-Hill Book Company.

**Tannenbaum, Harold E., Beulah Tannenbaum, Nathan Stillman, and Myra Stillman. 1967.** *Teachers Manual for Mapping.* New York, New York: Webster Division, McGraw-Hill Book Company, P.48.

## Naval Archeology

## Nautical Vocabulary:

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<b>Site Plan-</b>	A detailed drawing of a collection of artifacts and or features left by people who once lived or worked in a specific place.
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<b>Trilateration-</b>	Applying the SSS theorem to create a survey of a site. The measurement along the Baseline and the distance from the Datum (two points on the baseline) to the artifact. This data is recorded on a scale drawing with a straight edge and compass to create a site plan of shipwreck.
<b>Windlass-</b>	Shaft to wind sail rigging on. Also used to wind anchor chain or rope.



**Figure One: Mock Shipwreck**  
**Label all of the parts of the ship that you can using the Vocabulary list.**



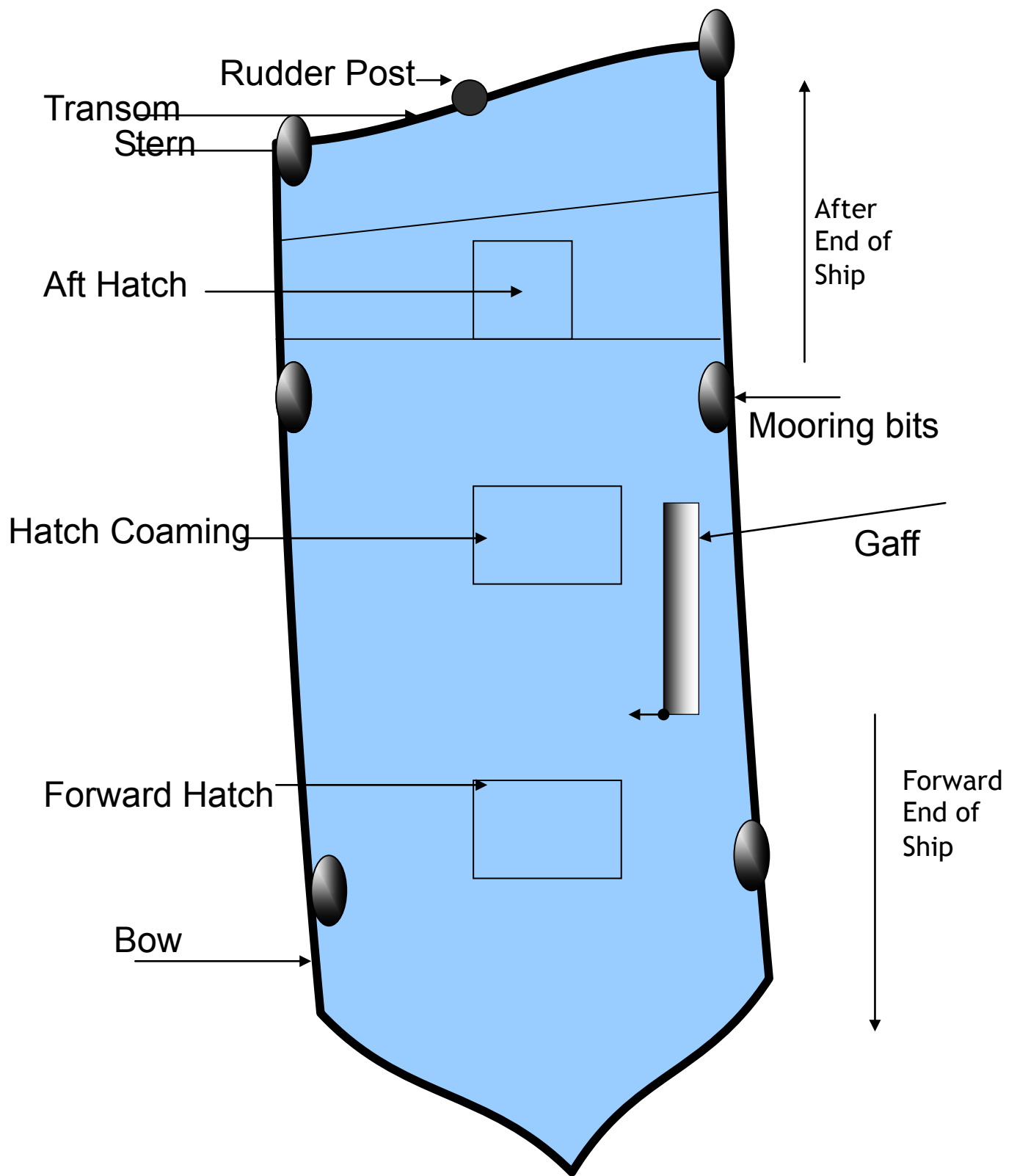


Figure Two: Answer Key to Activity “Mock Shipwreck”

## Naval Archeology

## Using Geometry to Map A Shipwreck

Company Name: \_\_\_\_\_

Date: \_\_\_\_\_

### Dive Roster:

1. Zero Diver: \_\_\_\_\_
2. Reel Diver: \_\_\_\_\_
3. Protractor Diver: \_\_\_\_\_
4. Recorder Diver: \_\_\_\_\_
5. Sketch Artist: \_\_\_\_\_
6. Master Diver: \_\_\_\_\_

## Day One: Group Organization

Group Goals: Each group is assigned a number

1. Name your shipwreck salvage company: (10 points)
2. Job Assignments (if groups are smaller the Reel diver and Protractor diver can share responsibilities): (20 points)
  - a. **Zero Diver:** The diver that holds the zero end of the tape measure.
  - b. **Reel Diver:** The diver that holds the end of the tape that is measured from Datum to artifact.
  - c. **Protractor Diver:** The diver that measures angle from Datum to artifact.
  - d. **Recorder Diver:** Records data collected by other divers.
  - e. **Sketch Artist Diver:** Sketches and records attributes of artifacts: ie. Condition, color, orientation. Overall sketch of the site.
  - f. **Dive Master:** Records bottom time (**8 minutes at this depth**), making sure that all divers are safe and not experiencing symptoms of narcolepsy, fatigue, and making sure that they do not get tangled in the wreck.

### Individual Goal: (25 points)

Read vocabulary. Use the vocabulary sheet to label the “Mock Shipwreck” handout.

**Bonus:** Any other objects listed in vocabulary list that you can sketch in a picture you can get 5 bonus points for your company.

# Naval Archeology

## Using Geometry to Map A Shipwreck

Company Name: \_\_\_\_\_

Date: \_\_\_\_\_

### Dive Roster:

1. Zero Diver: \_\_\_\_\_
2. Reel Diver: \_\_\_\_\_
3. Protractor Diver: \_\_\_\_\_
4. Recorder Diver: \_\_\_\_\_
5. Sketch Artist: \_\_\_\_\_
6. Master Diver: \_\_\_\_\_

## Day Two: Dive the Wreck

**Group Goals:** While waiting for your groups turn to dive. Plan your dive. Sketch any more nautical objects. (5 bonus points each)

**When you dive record information on data sheet. (50 points)**

**When your group returns, discuss what you saw and add to the sketch. (50 points for sketch)**  
**Your company will receive extra points for noticing dive conditions.**

**NOTICE: Penalties (-5points)**

1. **Delay of dive: if your company is not ready when called on**
2. **You talk you drown, or at least cough really hard. Your sketch artist is the only non-diver therefore he/she may talk.**
3. **Unsafe procedures: as determined by captain (teacher)**
4. **Disturbing, destroying or stealing from the wreck**

**PIGGY DIVERS RUIN OUR WRECKS!**

5. **If the divers run out of air: We only have 8 minutes of air in our tanks**

## DIVE PLAN

1. Locate first artifact to be measured. This is object 1
2. Sketch artist make sketch in the vicinity of the artifact
3. Record point number on sketch
4. Zero diver swims to artifact and holds zero end of tape at artifact.
5. Reel diver stays at Datum 1 point on baseline: Measure distance
6. Protractor Diver stays at Datum 1 point on baseline: Measure Angle
7. Recorder: record distance and angles to artifact from Datum 1
8. Reel Diver and Protractor Diver swim to Datum 2 (decide where Datum 2 makes sense)
9. Recorder: record Datum 2
10. Reel diver stays at Datum 2 point on baseline: Measure distance
11. Protractor Diver stays at Datum 2 point on baseline: Measure Angle
12. Zero Diver Swims to next artifact this is object 2

Repeat until all objects are recorded.

**NOTE: Remember Dive Master to keep track of bottom time and remaining air**



# Naval Archeology

## Using Geometry to Map A Shipwreck

Company Name: \_\_\_\_\_

Date: \_\_\_\_\_

### Dive Roster:

1. Zero Diver: \_\_\_\_\_

2. Reel Diver: \_\_\_\_\_

3. Protractor Diver: \_\_\_\_\_

4. Recorder Diver: \_\_\_\_\_

5. Sketch Artist: \_\_\_\_\_

6. Master Diver: \_\_\_\_\_

## Day Three: Map the Wreck

### Plotting Triangulation and Trilateration Data

Divide your company into two committees:

#### Trilateration Committee:

1. Zero Diver: \_\_\_\_\_

2. Protractor Diver: \_\_\_\_\_

3. Sketch Artist: \_\_\_\_\_

Use the “Plotting Trilateration Data” handout to map the site on graph paper

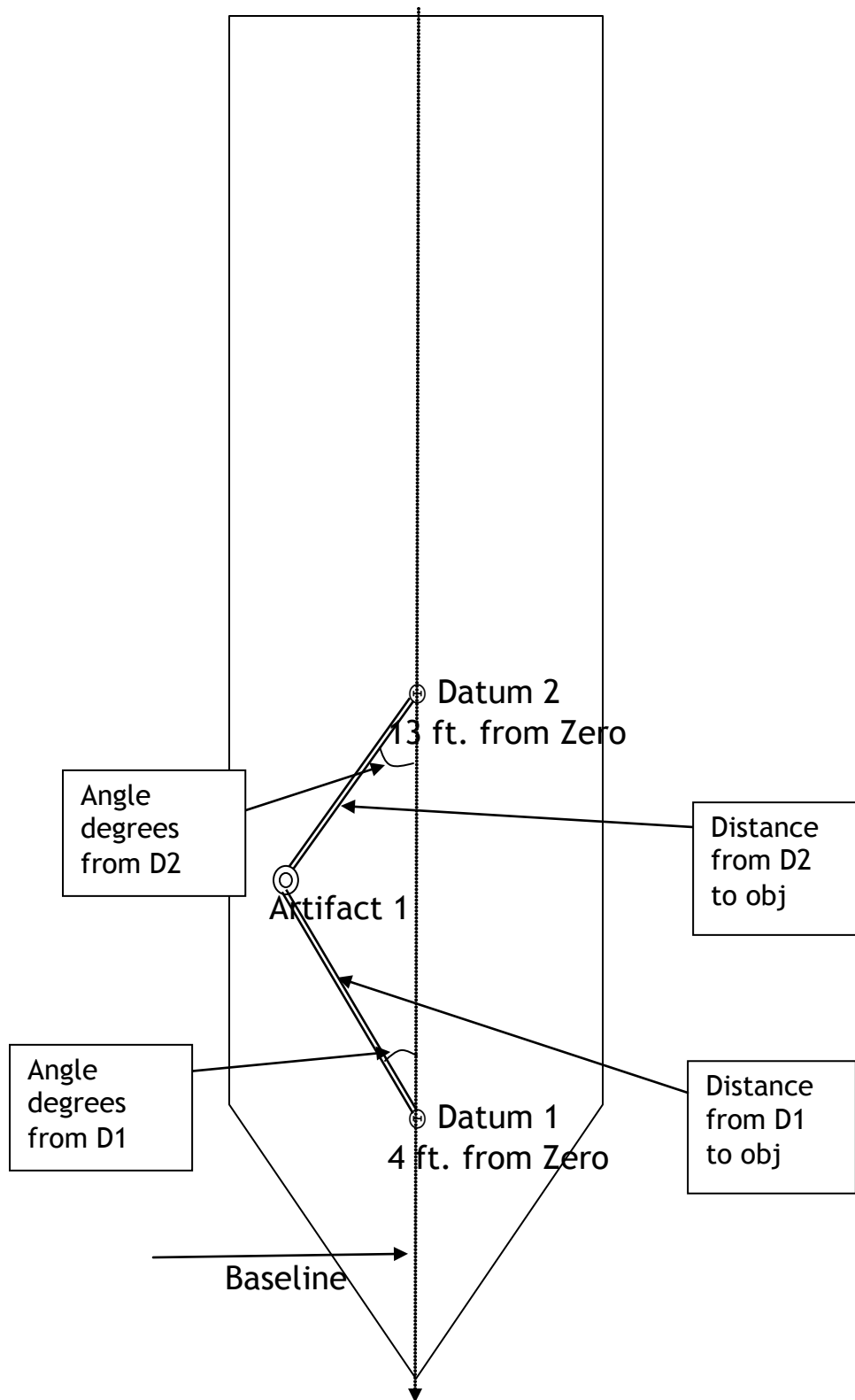
#### Triangulation Committee

1. Reel Diver: \_\_\_\_\_

2. Recorder Diver: \_\_\_\_\_

3. Master Diver: \_\_\_\_\_

Use the “Plotting Triangulation Data” handout to map the site on graph paper



### **Plotting Trilateration Data (100 points)**

1. Begin by drawing the baseline to an appropriate scale with a straight edge
2. Look at the first line of data from your dive data. Mark the Datum 1 and Datum 2 on the graph
3. Using a compass draw an arc centered on Datum 1 with a radius that equals D1 to obj.
4. Using a compass draw an arc centered on Datum 2 with a radius that equals D2 to obj.
5. Where the two arcs intersect is the location of Artifact 1. Label this on your drawing with a pen and erase your arcs.
6. NOTE: Make sure that you are plotting the intersection that is on the correct side of the wreck.
7. Label the horizontal and vertical distance from the zero point on the baseline.

You will be graded based on the accuracy of these numbers:

**5 POINTS EACH**  
**20 points for neat work**  
**120 points possible**

### **Plotting Triangulation Data (100 points)**

1. Begin by drawing the baseline to an appropriate scale with a straight edge
2. Look at the first line of data from your dive data. Mark the Datum 1 and Datum 2 on the graph
3. Using a protractor draw an angle with vertex on Datum 1 with degrees that equals deg D1 to obj.
4. Using a protractor draw an angle with vertex on Datum 2 with degrees that equals deg D2 to obj.
5. Where the two lines intersect is the location of Artifact 1. Label this on your drawing with a pen and erase your lines.
6. NOTE: Make sure that you are plotting the intersection that is on the correct side of the wreck.
7. Label the horizontal and vertical distance from the zero point on the baseline