AOE POE Integrated Curriculum Unit: Bombs Away

# Lesson 3.1

# Geometry

# Ballistic Missile Range

In this lesson, students apply their knowledge of several different mathematical concepts in order to adjust the calculation of ballistic missile range to account for the curvature of the Earth.

This lesson is expected to take two class periods.

## Lesson Framework

### Learning Objectives

Each student will:

- Apply the formula for arc length to solve for either arc length or the central angle.
- Apply knowledge of sine, cosine, and tangent to calculate a chord length given an arc length and a radius.
- Calculate the range of a ballistic missile, accounting for the curvature of the Earth.

### Academic Standards

- Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships. (NCTM Standards for School Mathematics, Grades 9–12, Geometry)
- Specify locations and describe spatial relationships using coordinate geometry and other representational systems. (NCTM Standards for School Mathematics, Grades 9–12, Geometry)
- Apply transformations and use symmetry to analyze mathematical situations. (NCTM Standards for School Mathematics, Grades 9–12, Geometry)
- Use visualization, spatial reasoning, and geometric modeling to solve problems. (NCTM Standards for School Mathematics, Grades 9–12, Geometry)

## Assessment

| Assessment Product | Assessment Criteria |
|---|---|
| Ballistic Missile Problems worksheet | Check worksheet for completion and accuracy |

## Prerequisites

- Working knowledge of sine, cosine, and tangent
- Working knowledge of trajectory motion

# Instructional Materials

## Teacher Resources

- Teacher Resource 3.1.1—Background Information: Ballistic Missiles
- Teacher Resource 3.1.2—Answer Key: Ballistic Missile Problems

## Student Resources

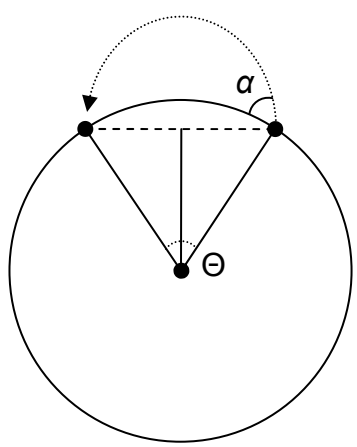
- Student Resource 3.1.1—Worksheet: Arc Length
- Student Resource 3.1.2—Worksheet: Ballistic Missile Range
- Student Resource 3.1.3—Worksheet: Ballistic Missile Problems

## Equipment and Supplies

- Large spherical ball (yoga ball, basketball)
- Small people figures (e.g., from LEGO™ kits)

# Lesson Steps

| Step | Min. | Activity |
|---|---|---|
| | | **CLASS PERIOD 1** |
| **1** | **20** | **Class Discussion: Curvature of the Earth**<br>Draw a quick trajectory on the board. Ask students what assumptions they are making when they calculate the distance traveled by ballistic objects.<br>• There is no air resistance.<br>• The Earth is flat.<br>**Air resistance** is a factor that comes into play a great deal in real-world calculations. Students should recall that many of the simulation programs available online account for air resistance. However, none of the simulations have adjusted for the fact that the Earth is not actually flat. Ask students why it seems acceptable not to take the Earth's curvature into account when doing trajectory problems about everyday objects.<br>Guide the discussion so that students conclude that over the distances traveled by everyday objects, the Earth's curvature is so slight as to be negligible for all intensive purposes. However, over very long distances—i.e., thousands of kilometers—the Earth's curvature is more pronounced. As an example, bring in a large ball (basketball or yoga ball) and some small figures, such as toy LEGO people. Ask students to imagine that they are a few centimeters tall and living on the surface of the basketball. If the two figures are very close, it seems that the surface distance between them is horizontal. However, if you put them on opposite sides of the ball, clearly the surface space is not horizontal. Move the figures closer together. Ask students how close you will have to move them before it seems like the land between them is horizontal once more. (It should be pretty close.) |
| **2** | **30** | **Direct Instruction: Arcs and Radians**<br>Tell students that in order to be able to figure out the "real" distance between two cities, they will need to understand **arcs** and **arc length**, as well as apply some other geometry concepts. Introduce or review the concepts of **arcs** and **radians** as you would in your regular instruction, or use the Arc Length worksheet (Student Resource 3.1.1). Allow students some time in class to practice arc length and radian problems. |
| | | **CLASS PERIOD 2** |
| **3** | **5** | **Homework Review: Arcs and Radians**<br>Review the answers to the worksheet with the entire class. |
| **3** | **40** | **Direct Instruction: Ballistic Missile Trajectories**<br>***Keep in mind this is an enormous simplification of the work that goes into calculating the trajectory of actual ballistic missiles.*** |

| Step | Min. | Activity |
|---|---|---|
| | | Begin with a little background information on the size of the Earth:<br><br>Our planet (or any rotating planet) is not true sphere. A more appropriate term for the Earth's shape is an **oblate spheroid**. Rotational momentum forces matter to bunch up in the middle. For us, this means that the planet is slightly fatter at the equator. The diameter at the equator is approximately 12,756 km, while the diameter from the North Pole to the South Pole (the shortest diameter) is approximately 12,714 km. Compared to the overall size of the planet, this is not a large difference, so the Earth is considered only *slightly* oblate. For most intents and purposes, it is acceptable to represent the Earth as a sphere, using average measures of radius and circumference.<br><br>Next, provide some basic information about ballistic missiles:<br><br>**Ballistic missiles** are missiles that have a ballistic trajectory governed by the laws of classical mechanics. Ballistic missiles are powered only briefly during initial flight. Once the initial fuel burn is complete, the course of the missile is set and cannot be changed.<br><br>Ballistic missiles intended to be used as weapon delivery systems typically need to travel over long distances. The United States maintains an arsenal of Intercontinental Ballistic Missiles (ICBMs) that can accurately strike a target over 5,500 kilometers away. There are two formulas typically used in physics classes to calculate the range of a projectile<br><br>$$x = v_{ox}t \text{ and } x = \frac{v_0^{\,2}\sin 2\alpha}{g}$$<br><br>Where $v$ is the initial velocity, $t$ is time, $g$ is gravity, and $\alpha$ is the launch angle.<br><br>Both of these assume that distance in the $x$ direction is perfectly horizontal, implying a flat Earth. This is an acceptable assumption over short ranges, because the radius of the Earth is so large. However, it cannot be applied at long ranges where the curvature of the Earth will be apparent.<br><br>When planning trajectories over long distances, the distance calculated using the traditional projectile motion formula is actually measuring the chord length between the points, rather than the arc length.<br><br>  <br><br><br>Now this problem can be broken down into basic geometry steps. Have students take notes on the Ballistic Missile Range worksheet (Student Resource 3.1.2).<br><br>If we know the arc length between the two points, then we can solve for the central angle, Θ.<br><br>Once we have the Θ, we can bisect it to form two equivalent right triangles, that each have an interior angle of ½ Θ and a hypotenus equal to the radius of the Earth.<br><br>Because we now have one angle and the hypothenuse, we can use SOH CAH TOA to find half of the chord length. Opposite equal sine |

| Step | Min. | Activity |
|---|---|---|
| | | times hypotenuse. Substituting in the appropriate variables gives the formula:<br>Chord length = $2r\ sin(\frac{1}{2}\Theta)$<br>Now that students can use this caluation to solve for the official distance, they can use the standard trajectory motion formulas from Lesson 2.1 to solve the problems. |
| **5** | **5** | **Practice Problems: Ballistic Missile Range Problems**<br>Pass out the Ballistic Motion Problems worksheet (Student Resource 3.1.3) and have students begin solving them in class. Have students finish the problems as homework and review the answers the next day. |

AOE POE Integrated Curriculum Unit: Bombs Away

# Lesson 3.1

# Ballistic Missile Range

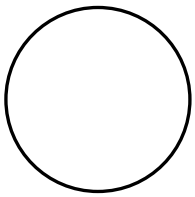
## Student Resources

| Resource | Description |
|---|---|
| Student Resource 3.1.1 | Worksheet: Arc Length |
| Student Resource 3.1.2 | Worksheet: Ballistic Missile Range |
| Student Resource 3.1.3 | Worksheet: Ballistic Missile Problems |

**Student Resource 3.1.1**

# Worksheet: Arc Length

As you already know, the circumference of a circle is calculated using the formula **C = 2πr**. What if you want to know the length of only a portion of the circumference, otherwise known as an **arc length**? For example, what would be the length of a semicircle?



$2\pi r$

$\frac{2\pi r}{2} = \pi r$

?

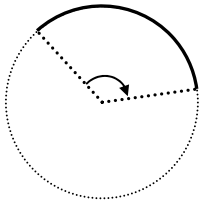
Using the same logic, how would you calculate the arc length of a quarter of a circle, an eighth of a circle, or a third of a circle?

Quarter circle arc length = _____

Eighth of a circle arc length = _____

Third of a circle arc length = _____

But what if you didn't know exactly what fraction of the circle it was? What if you only knew the central angle of the arc?



Remember that the central angle of a complete circle is 360°.

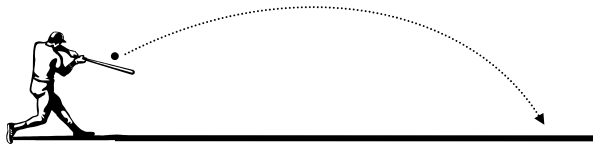
| Measure of the **central angle (CA)** | Measure of the **degrees in a circle** | **CA** / 360° | Arc length ***L*** | Circumference ***C*** | ***L*** / ***C*** |
|---|---|---|---|---|---|
| 360° | 360° | 360°/360° = 1 | 2πr | 2πr | $\pi 2r / \pi 2r = 1$ |
| 180° | 360° | 180°/360° = 0.5 | πr | 2πr | $\pi r / \pi 2r = 0.5$ |
| 90° | 360° | | | 2πr | |
| 45° | 360° | | | 2πr | |
| 30° | 360° | | | 2πr | |
| 60° | 360° | | | 2πr | |

**Student Resource 3.1.2**

# Worksheet: Ballistic Missile Range

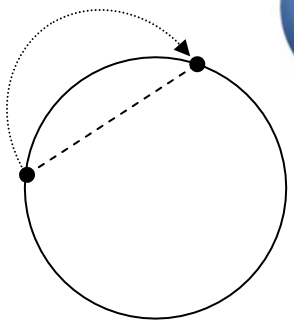
When throwing a ball or shooting fireworks, the horizontal distance traveled by the object can be calculated using the formula:

$$x = v_{0x}t$$



Remember though that this formula is used for calculating **horizontal distance**. That is, it assumes that the Earth is flat! This is a reasonable assumption over short distances. The curvature of the Earth is so slight over the distance you might throw a ball that we can assume the Earth is flat in that situation.

However, as you can see from the picture to the right, when the trajectory covers a very long distance (e.g., all the way to another country), the surface of the Earth is definitely not flat between the initial launch and final landing locations.



If we could look at a cross section of the Earth in this case, we would see the trajectory looking something like this. The surface distance between the two points is actually the arc length between the two points. The shortest distance (and the distance that we would use in our trajectory motion problems) is actually the chord length between the two points. How can we solve for the chord length in this circumstance?

**Student Resource 3.1.3**

# Worksheet: Ballistic Missile Problems

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AOE POE Integrated Curriculum Unit: Bombs Away

# Lesson 3.1

# Ballistic Missile Range

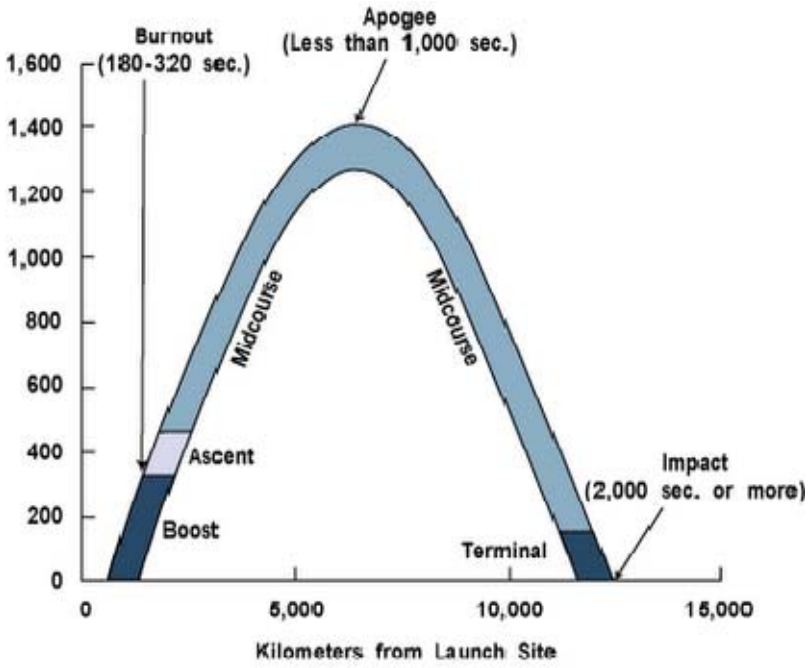
## Teacher Resources

| Resource | Description |
|---|---|
| Teacher Resource 3.1.1 | Background Information: Ballistic Missiles |
| Teacher Resource 3.1.2 | Answer Key: Ballistic Missile Problems |

**Teacher Resource 3.1.1**

# Background Information: Ballistic Missiles

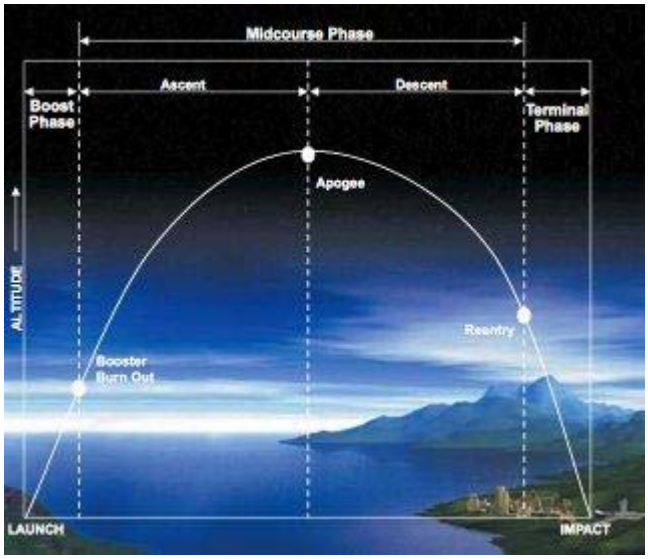
A ballistic missile is a missile that is guided (powered) in the ascent portion of a high arch-trajectory and freely falling in the descent (see illustration).



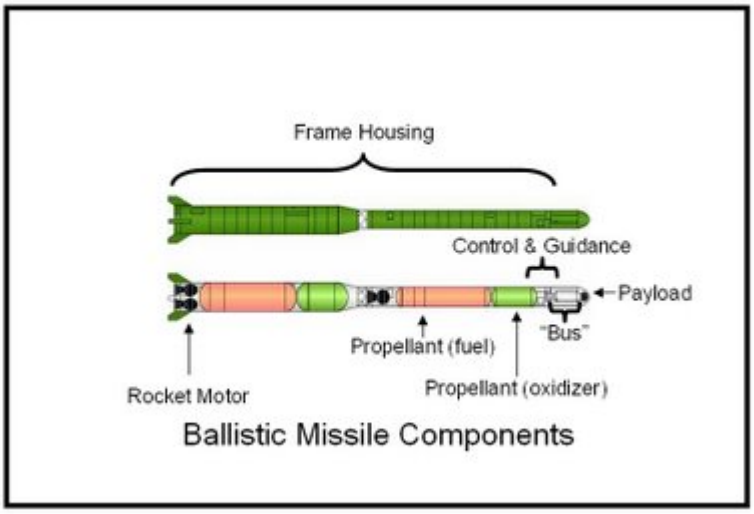

The ranges of ballistic missiles are categorized into the following classes:

- Short-range: less than 1,000 km. Typically these are called “battlefield” missiles and are represented by the SCUD-class.
- Medium-range: 1,000–3,000 km.
- Intermediate-range: 3,000–5,500 km.
- Intercontinental-range: +5,500 km. Only Russia, the US, UK, France, and China have demonstrated these kind of capabilities, with examples being the SS-27 (Russia), Minuteman III (US), Trident (UK and US; this is a Submarine-Launched Ballistic Missile), M-5 (France—also an SLBM), and the CSS-4 (China). North Korea is developing a capability with the Taepo Dong 2.

There are three phases to the flight of a ballistic missile: ascent or boost, mid-course, and terminal or free-fall phases. These terms are important because they also define the three areas that characterize a missile defense system.

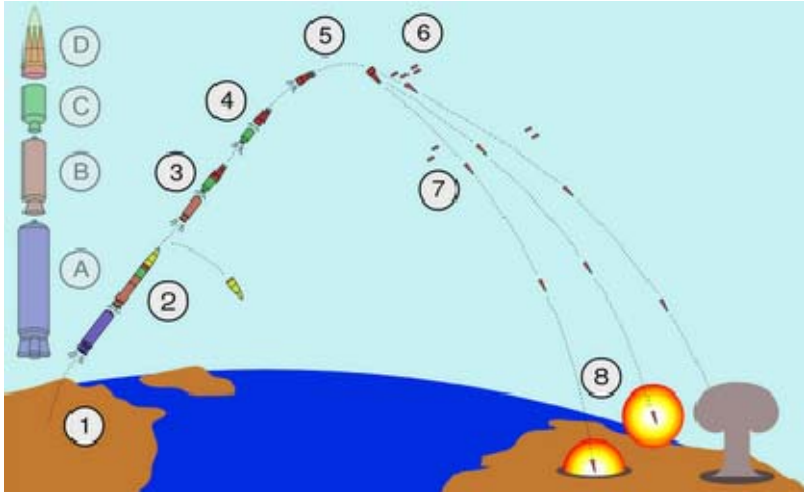



- **Boost phase**: During this phase, the missile is applying thrust to gain acceleration while establishing its trajectory downrange. During this phase, the fuel from all stages is exhausted. Typically, this phase lasts anywhere from 3 to 5 minutes endo-atmospheric and generates a highly visible plume of exhaust gas that is critical to initial detection and warning.
- **Mid-course phase**: This is the longest part of the flight—usually about 20–30 minutes for ICBMs—and occurs outside of the atmosphere for ICBMs. IRBMs will see a portion of their mid-course flight exo-atmospheric. SR- and MRBMs typically will remain endo-atmospheric, but they do skirt the edge of space at their apogee. At this time, penetration aids and countermeasures are dispensed along with multiple warheads (if equipped).
- **Terminal phase**: The terminal phase is marked by re-entry into the atmosphere with exceptional energy being generated in free fall (up to 14,000 mph). Penetration aids and debris accompanying the warhead(s) are usually stripped away by the atmosphere at this point as well. This phase usually lasts only 1–2 minutes.



**Missile construction**: Major components of a ballistic missile consist of the following:

- **Frame housing**: This is usually thought of as the missile's airframe (minus the payload) and is made of aluminum or, more recently, composites (fiberglass re-enforced plastics typically) for strength and light weight.
- **Rocket motor or engine**: These may be either solid- or liquid-fueled or a combination (liquid-fueled lower stages, solid fuel upper stage).
- **Propellant**: This includes both the fuel (e.g., liquid hydrogen, hydrazine) and an oxidizer like liquid oxygen or nitrogen tetroxide. There are actually three types of propellant, each with its own inherent advantages and disadvantages:
    - Liquid:
        - Cryogenic: must be kept extremely cold and fueled just prior to launch but provides a 40% higher impulse than other liquid variants;
        - Hypergolic: liquid at room temperature, and when combined, spontaneously combusts requiring no ignition source; or
        - Monopropellant: provides the best power performance and re-start capability, but is highly unstable, exceptionally toxic, and corrosive.
    - Solid: preferred for mobile systems as it may be pre-loaded for storage/transportation, but it is vulnerable to cracking and has no shut-off/re-start capability; and
    - Hybrid: solid fuel/liquid oxidizer—provides a safe, storable capability as well as shut-off/restart, but it is very expensive and technically demanding to produce.
- **Control and Guidance systems**: consists of a Flight Path Control System (determines flight path) and Attitude Control System (keeps missile on path). May be provided by:
    - Inertial guidance: based on an inertial platform based on mechanical or laser ring gyros, predominately used in the boost phase;
    - Celestial: using stars to align the missile on track—usually mid-course, but may also be combined with GPS or GLONASS satellite navigation systems; and
    - Terminal: using onboard sensors (e.g., the Pershing II used terrain-matching digital radar in the terminal phase to achieve a CEP of less than 10 meters).
- **Vehicle launch system (or BUS)**: the vehicle that carries and dispenses the warheads and penetration aids.
- **Payload**: the re-entry vehicle(s) which may be:
    - Unitary: a single, non-separating warhead that remains attached to the body such as the Scud;
    - Multiple Re-entry Vehicles (MRV): not independently targetable, used to ensure Pk by overwhelming a point defense with warheads with the expectation that some will get through terminal defenses; and
    - Multiple Independently Targeted Re-Entry Vehicles (MIRVs): individual RVs assigned targets independently along the flight path. Complicates defenses by increasing the defended area.




Maneuverable Re-Entry Vehicle (MaRV): via either RV body shaping or use of deployable mini-aerodynamic fins, the MaRV permits terminal area maneuvering or flight path extension to offset defensive measures established on predicted re-entry paths.

**Teacher Resource 3.1.2**

# Answer Key: Ballistic Motion Problems

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AOE POE Integrated Curriculum Unit: Bombs Away

# Lesson 3.2

# U.S. History

# Cuban Missile Crisis

In this lesson, students will analyze and evaluate conditions, actions, and motivations that contributed to conflict and cooperation within and among nations involved in the Cuban Missile Crisis. To do so, students will read and take on roles representing the different perspectives preceding that event.

This lesson is expected to take at least two class periods.

## Lesson Framework

### Learning Objectives

Each student will:

- Summarize the perspectives of each of the three major sides involved in the Cuban Missile Crisis.
- Assume the role of a specific member of Kennedy's executive advisory committee during the crisis.
- Analyze Kennedy's response to presence of missiles in Cuba, given his available options.

### Academic Standards

- The student understands the international origins and domestic consequences of the Cold War. (NCHS National History Standards, U.S. History, Era 9, Standard 2A)
- The student understands United States foreign policy in Africa, Asia, the Middle East, and Latin America. (NCHS National History Standards, U.S. History, Era 9, Standard 2B)
- The student understands the political debates of the post-World War II era. (NCHS National History Standards, U.S. History, Era 9, Standard 3B)

## Assessment

| Assessment Product | Assessment Criteria |
|---|---|
| One-page essay that identifies a response to the Cuban missile situation, along with justification for the proposed action; the essay will include reasons why other possible actions were rejected. | Teacher Resource 3.2.4—Rubric: Cuban Missile Crisis Essay |

## Prerequisites

- Working knowledge of Cold War positions prior to 1962

# Instructional Materials

## Teacher Resources

- Teacher Resource 3.2.1—Roles: Panel Discussion
- Teacher Resource 3.2.2—Chart: Reasons for Cuban Missiles
- Teacher Resource 3.2.3—Background Reading: ExComm Members
- Teacher Resource 3.2.4—Rubric: Cuban Missile Crisis Essay

## Student Resources

- Student Resource 3.2.1—Reading: Cuban Missile Crisis
- Student Resource 3.2.2—Worksheet: Crisis Reenactment
- Student Resource 3.2.3—Reading: Kennedy's Decision
- Student Resource 3.2.4—Reading: Global Consequences

## Equipment and Supplies

- None

# Lesson Steps

| Step | Min. | Activity |
|---|---|---|
| | | **CLASS PERIOD 1** |
| **1** | **35** | **Panel Discussion: Setting the Stage**<br>Ask students to remember or imagine a situation when they have provoked someone they didn't like. What was their reason for behaving that way? What do they think the other person would say the reason was?<br>The day before the lesson, select five students to play roles of several key figures and historians who each have a view of why missiles were placed in Cuba in 1942. Assign students roles from Teacher Resource 3.2.1—Roles: Panel Discussion.<br>Assemble the panel in front of the class and conduct a discussion about the "situation" in Cuba. Ask the panel questions that allow them to elaborate each of their perspectives to the rest of the class.<br>With the class, make a chart on the board summarizing the different reasons and the sources. Ask the class if there is a clear way to categorize the different reasons. Help students to recognize that some of the reasons were in Cuba's interest, and some were in the former Soviet Union's interest. Take a poll on which reasons students find the most convincing. Examine the sources of the different reasons. Ask the class if it's possible to identify the "real" reason why missiles were placed in Cuba?<br>Finish the discussion by explaining how it is difficult to know the "truth" about historical events because different perspectives on actions and events influence how they are interpreted. |
| **2** | **15** | **Reading: Cuban Missile Crisis**<br>Pass out the Cuban Missile Crisis reading (Student Resource 3.2.1). Select individual students to read each paragraph aloud and discuss the questions with the class in between the readings. |
| | | **CLASS PERIOD 2** |
| **3** | **varies** | **Role Play: Cuban Missile Crisis Reenactment**<br>Pass out the Crisis Reenactment worksheet (Student Resource 3.2.2). Have students read the scenario and the reactions of the ExComm committee. Using the chart provided in the worksheet, students should come to their own conclusions about how the United States should have responded.<br>You may wish to extend the lesson by having students assume the role of a particular ExComm member and research that role in greater depth, possibly as a Jigsaw activity (see the NAF Comments from some of the major figures summarized in Teacher Resource 3.2.3—Background Reading: ExComm Members). |

| Step | Min. | Activity |
|---|---|---|
| | | As students finish their work, circulate among the class and make a quick tally of which students have chosen each strategy. Break the students into groups of six to role-play the committee discussions. As you are assigning groups, be sure that each group is made up of students with differing opinions about what the decision should be.<br><br>The group should come to a unanimous decision about which action(s) to take. Each student should write a one-page essay that justifies the decision their group chose and that also explains why the other options were rejected. |
| **4** | **20** | **Reading: Kennedy's Decision**<br><br>Pass out the Kennedy's Decision reading (Student Resource 3.2.3). Have students compare and contrast the decisions they made during their role-plays with the actual decision that was made. |
| **5** | **5** | **Essay: Cuban Missile Decision**<br><br>Pass out the Global Consequences reading (Student Resource 3.2.4). Assign the reading for homework, along with a one-page essay that identifies a response to the Cuban missile situation and presents a justification for the proposed action. Tell students to include in their essays the reasons why other possible actions were rejected. |

AOE POE Integrated Curriculum Unit: Bombs Away

# Lesson 3.2

# Cuban Missile Crisis

## Student Resources

| Resource | Description |
|---|---|
| Student Resource 3.2.1 | Reading: Cuban Missile Crisis |
| Student Resource 3.2.2 | Worksheet: Crisis Reenactment |
| Student Resource 3.2.3 | Reading: Kennedy's Decision |
| Student Resource 3.2.4 | Reading: Global Consequences |

**Student Resource 3.2.1**

# Reading: Cuban Missile Crisis

One of the most dramatic moments of the Cold War came in October 1962: The Cuban Missile Crisis. On October 14, a U-2 spy plane flying reconnaissance over Cuba observed alarming activity. Photographs taken by the U.S. plane revealed bases for Soviet medium-range ballistic missiles being built on Cuba, less than 90 miles from Florida. This was especially alarming because missiles so close, if operational and equipped with nuclear warheads, could reach and destroy American targets with little warning. It was clear this development was a serious threat to national security, and the missiles could not be allowed to stay in Cuba.

**Discuss: What do you think are the options?**

Over the next several days, President Kennedy assembled his top advisors in a series of meetings to discuss the U.S. response. This group, the Executive Committee (ExComm) of the National Security Council, included military leaders, experts on Latin America, CIA representatives, cabinet ministers, and personal friends of the President. A direct military response, ranging from air strikes on the missile bases to a full-scale invasion of Cuba, was considered immediately. However, there were serious concerns that a military action on Cuban soil might provoke Cuba's ally, the Soviet Union, into nuclear war.

**Discuss: Would you have chosen to attack?**

**Reading: Student Resource 3.2.2**

# Worksheet: Crisis Reenactment

## Directions

*Read the scenario and reactions below and fill in the chart. Be sure to include your own reactions, not just the reactions listed. Make a decision about what you think you would have done if you were in President Kennedy's place. Be sure to consider issues such as the number of people who may be killed, how successful your action is likely to be, future relationships with other countries, and how the decision will influence the elections that are about to take place in the United States. After each person has made a decision, go to your teacher-assigned group and discuss the situation. Then make a group decision about which strategy to adopt.*

## Scenario

When informed about the presence of missiles in Cuba, President Kennedy assembled a group of advisors to discuss what the American response should be. The next few days were tense, and the group met several times to consider a range of strategies, including the following:

1. Do nothing. We don't really have the right to complain. After all, the United States had military bases in more than 100 countries, including Cuba. Also, we already have nuclear missiles in several countries close to the Soviet Union.
2. Negotiate. Offer the Soviet Union a deal: we'll withdraw our nuclear missiles that are close to them (Turkey, Italy) if they withdraw the Cuban missiles close to us.
3. Invasion. Send U.S. troops to Cuba to overthrow Castro's government. The missiles could then be put out of action, and the Soviet Union could no longer use Cuba as a military base.
4. Blockade of Cuba. Use the U.S. Navy to stop military equipment from reaching Cuba from the Soviet Union.
5. Bomb Missile Bases. Carry out conventional air strikes against missiles and other military targets in Cuba.
6. Nuclear Weapons. Use nuclear weapons against Cuba and/or the Soviet Union.

## Reactions

When discussing these strategies, President Kennedy and his advisers had to take into consideration how both the Soviet Union and Cuba would react to decisions made by the United States. The comments below reflect the range of possible consequences discussed by the committee.

- They'll knock out our missile bases in Turkey, Italy, or Britain. Under our NATO Treaty, we'd be obligated to knock out a base inside the Soviet Union.
- Castro might announce that he would execute two Bay of Pigs prisoners for each day it continued.
- It would be the start of a nuclear war.

- Cuban and Soviet troops would attack the U.S. base at Guantanamo Bay.
- The Latin Americans would produce more figures like Fidel Castro.
- It could mean the end of the world.
- It will take too much time, and the Soviets would be able to finish building the sites.
- The next House of Representatives is likely to have a Republican majority.
- The Soviet Union would blockade Berlin.
- We would kill a lot of Russians. Khrushchev would have to take action.
- The Russians would move into West Berlin.
- The Cuban communists would take to the hills and fight a guerrilla campaign.
- Thousands and thousands of civilians would be killed. Some of the nuclear weapons may be used before we could destroy them.
- No country would ever trust us again.

## Analysis

Based on your information, what would you do? Fill in the chart below as a way to help you think through your options.

| Strategy | Possible Reaction of Soviet Union/Cuba | Other Potential Consequences |
|---|---|---|
| Do Nothing | | |
| Negotiate | | |
| Invasion | | |
| Blockade of Cuba | | |
| Bomb Missile Bases | | |
| Nuclear Strike | | |

What is your decision and why?

## Role Play

Break into groups of six and come to agreement about the best strategy.

**Student Resource 3.2.3**

# Reading: Kennedy's Decision

On October 20, 1962, President Kennedy chose instead to impose a naval blockade on Cuba. The blockade had several advantages. First, it would prevent any additional Soviet weapons from entering Cuba. Second, it was a display of military strength that signaled the determination of the United States. Third, and especially important under the circumstances, it offered flexibility to both Washington and Moscow. On the President's side, the blockade left open the option of increasing pressure on Moscow with the threat of escalation. On the Soviet side, the president's brother, Attorney General Robert Kennedy, argued that because a blockade wasn't exactly an attack, the Soviet leader, Premier Khrushchev, would have "some room for maneuver."

The crisis became public on October 22, when President Kennedy addressed the nation. Americans and people around world waited anxiously. How would the Kremlin react? Would the Moscow launch an attack on cities in the United States? Would the Soviet navy obey or challenge the blockade? The world had never seemed so close to nuclear war.

**Student Resource 3.2.4**

# Reading: Global Consequences

The Cuban Missile Crisis was the first and only nuclear confrontation between the United States and the Soviet Union. The event appeared to frighten both sides, and it marked a change in the progress of the Cold War. Some of the direct consequences of the crisis included the following:

1. The two sides established a direct communications link that became known as the Hot Line. It was hoped that this would help prevent dangerous confrontations such as the Cuban Missile Crisis arising again.
2. Three months after the Cuban Missile Crisis, the United States secretly removed all of its nuclear missiles from Turkey and Italy.
3. A Test Ban Treaty was signed between the two countries in August 1963. The Treaty prohibited the testing of nuclear weapons in the atmosphere.
4. The 1,113 prisoners captured during the Bay of Pigs invasion were exchanged by Castro for $60 million in food, drugs, medicine, and cash.
5. The Soviet Union became determined to have a nuclear capability that was equal to the United States. This was achieved by 1972.
6. China accused the Soviet Union of being a “paper-tiger” and claimed to be the true leader of the Communist movement. The split between the Soviet Union and China became wider.
7. The United States became convinced that the Soviet Union would not go to war in support of another communist country. It has been argued that this encouraged the United States to help attempts to overthrow socialist and communist governments in Vietnam, Nicaragua, and Grenada.

AOE POE Integrated Curriculum Unit: Bombs Away

# Lesson 3.2

# Cuban Missile Crisis

## Teacher Resources

| Resource | Description |
|---|---|
| Teacher Resource 3.2.1 | Roles: Panel Discussion |
| Teacher Resource 3.2.2 | Chart: Reason for Cuban Missiles |
| Teacher Resource 3.2.3 | Background Reading: ExComm Members |
| Teacher Resource 3.2.4 | Rubric: Cuban Missile Crisis Essay |

**Teacher Resource 3.2.1**

# Roles: Panel Discussion

## Directions for the Class

*Assign the following five roles to students ahead of time so they can familiarize themselves with the perspective of the person they're representing. This will serve as background material for each of the five panel members. Take some time to discuss their roles with them before they present before the rest of the class.*

## Roles

| | |
|---|---|
| **ANDREI GROMYKO (1973)**<br>**Foreign Secretary of the Soviet Union**<br><br>Over several years, the United States had established offensive military bases around the socialist countries and, primarily, near the USSR borders. The placement of medium-range effective Soviet missiles in Cuba was undertaken only after the U.S. ruling circles continually rejected proposals to remove American military bases, including missile sites, on foreign territory. | **FIDEL CASTRO (1984)**<br>**President of Cuba**<br><br>It was necessary to make it clear to the United States that an invasion of Cuba would imply a war with the Soviet Union. It was then that they proposed the missiles. We preferred the risks, whatever they were, of a great tension, a great crisis, to the risks of the impotence of having to await a U.S. invasion of Cuba. |
| **DAVID DETZER (1980)**<br>**U.S. Historian**<br><br>One wonders, given Russian reluctance to move nuclear weapons from Soviet soil, if in fact they merely sent rockets and non-nuclear warheads. If the Kremlin's purpose was essentially political (for example, Berlin), all they needed to do was to give the appearance of nuclear capability. Moreover, sending atomic warheads to Cuba offered certain disadvantages. Something might go wrong—such as a ship sinking or a misfire, or even the Cuban government grabbing them. It seems at least possible that the Russians were bluffing. | **JAMES DANIEL AND JOHN HUBBELL (1963)**<br>**U.S. Historians**<br><br>The United States anticipated that by the mid-1960s they would have about of 1,500 ballistic missiles .The total number of Soviet missiles that could reach targets in the United States was about 125. But by moving medium- and intermediate-range missiles to Cuba, deep in the Western Hemisphere, Russia was rapidly narrowing the gap. The presence of Russian missiles in Cuba had drastically altered the balance of world power. |
| **NIKITA KHRUSHCHEV (1971)**<br>**Premier of the Soviet Union**<br><br>The United States had already surrounded the Soviet Union with its own bomber bases and missiles. We knew that American missiles were aimed against us in Turkey and Italy, to say nothing of West Germany. It was during my visit to Bulgaria that I had the idea of installing missiles with nuclear warheads in Cuba without letting the United States find out they were there until it was too late to do anything about them. Everyone agreed that America would not leave Cuba alone unless we did something. We had an obligation to do everything in our power to protect Cuba's existence as a Socialist country and as a working example to the other countries in Latin America. The Americans had surrounded our country with military bases and threatened us with nuclear weapons and now they would learn just what it feels like to have enemy missiles pointing at you; we'd be doing nothing more than giving them a little of their own medicine. | |

**Teacher Resource 3.2.2**

# Chart: Reasons for Cuban Missiles

*Draw the chart below on the board. Ask students for suggestion on how to fill it in, based on the information they've learned from the panel discussion. Suggested answers are included. After students have completed the chart, ask them what the two main reasons for placing missiles in Cuba appeared to be. Tell students to take a look at which reasons were given by which sources. Ask students which sources directly contradict each other. Ask them which sources they believe, and why? By the end of the activity, students should recognize that it can be difficult to determine "what really happened" with historical events. Different sides view the same event from different perspectives.*

| **Reason for Missiles** | **Source** | **Advantage?** |
|---|---|---|
| *Missiles were placed only after the United States continually refused to remove its own bases and missiles on foreign territory (near the USSR).* | *Andrei Gromyko, Foreign Secretary of the Soviet Union* | *USSR* |
| *Missiles were placed to prevent the United States from invading Cuba.* | *Fidel Castro, President of Cuba* | *Cuba* |
| *Missiles were only a bluff by the Soviets.* | *David Detzer, U.S. Historian* | *USSR* |
| *Missiles were placed to increase the number of Soviet missiles capable of striking the United States.* | *James Daniel and John Hubbell, U.S. Historians* | *USSR* |
| *Missiles were placed to protect Cuba from the United States and in reaction to U.S. missiles pointed at the USSR.* | *Nikita Khrushchev, Premier of the Soviet Union* | *Cuba and USSR* |

**Teacher Resource 3.2.3**

# Background Reading: ExComm Members

## Robert McNamara, Secretary of Defense

Secretary McNamara described his view as the “blockade route.” This route is aimed at preventing any addition to the strategic missiles already deployed to Cuba and eventually eliminating these missiles. He said in order to do this we should institute a blockade of Cuba and be prepared to take armed action in specified instances.

Secretary McNamara concluded by explaining that following the blockade, the United States would negotiate for the removal of the strategic missiles from Cuba. He said we would have to be prepared to accept the withdrawal of U.S. strategic missiles from Turkey and Italy and possibly agree to limit our use of Guantanamo to a specified amount of time. He added that we could obtain the removal of the missiles from Cuba only if we were prepared to offer something in return during negotiations. He opposed the suggestion that we should issue an ultimatum to the effect that we would order an air attack on Cuba if the missiles were not removed because it was too risky. He said he was prepared to tell Khrushchev that we consider the missiles in Cuba as Soviet missiles and that if they were used against us, we would retaliate by launching missiles against the USSR.

Secretary McNamara pointed out that SNIE 11-19-62, dated October 20, 1962, estimates that the Russians will not use force to push their ships through our blockade. He cited Ambassador Bohlen’s view that the USSR would not take military action, but would limit its reaction to political measures in the United Nations.

Secretary McNamara listed the disadvantages of the blockade route as follows:

1. It would take a long time to achieve the objective of eliminating strategic missiles from Cuba.
2. It would result in serious political trouble in the United States.
3. The world position of the United States might appear to be weakening.
4. Secretary McNamara cited the following as advantages:
5. It would cause us the least trouble with our allies.
6. It would prevent any surprise air attack on Cuba, which is contrary to our tradition.
7. It is the only military course of action compatible with our position as a leader of the free world.
8. It avoids a sudden military move that might provoke a response from the USSR that could result in escalating actions leading to general war.

Secretary McNamara stated that if we knew that a plane was flying nuclear warheads to Cuba, we should immediately shoot it down. Parenthetically, he pointed out there are now 6,000 to 8,000 Soviet personnel in Cuba.

Mr. McNamara cautioned that an air strike would not destroy all the missiles and launchers in Cuba, and at best, we could knock out two-thirds of these missiles. Those missiles not destroyed could be fired from mobile launchers that were not destroyed.

Secretary McNamara noted that the air strike planned by the Joint Chiefs involved 800 sorties. Such a strike would result in several thousand Russians being killed, chaos in Cuba, and efforts to overthrow the Castro government. He believed the probability was high that an air strike would lead inevitably to an

invasion. He doubted that the Soviets would take an air strike on Cuba without resorting to a very major response. In such an event, the United States would lose control of the situation, which could escalate to general war.

## Roswell Gilpatric, Deputy Secretary of Defense

Deputy Secretary Gilpatric saw the choice as involving the use of limited or unlimited force. He was prepared to face the prospect of an air strike against Cuba later, but he opposed the initial use of all-out military force such as a surprise air attack. He defined a blockade as being the application of the limited use of force and doubted that such limited use could be combined with an air strike.

## General Maxwell Taylor, U.S. Army

General Taylor reported that the Joint Chiefs of Staff favor an air strike on Tuesday when U.S. forces could be in a state of readiness. He said he did not share Secretary McNamara's fear that if we used nuclear weapons in Cuba, nuclear weapons would be used against us.

General Taylor responded that the risk of these missiles being used against us was less than if we permitted the missiles to remain there.

General Taylor said that the principal argument he wished to make was that now was the time to act because this would be the last chance we would have to destroy these missiles. If we did not act now, the missiles would be camouflaged in such a way as to make it impossible for us to find them. Therefore, if they were not destroyed, we would have to live with them and all the consequent problems for the defense of the United States.

General Taylor was doubtful that it would be possible to prevent the Russians from deploying warheads to Cuba by means of a blockade because of the great difficulty of setting up an effective air blockade.

General Taylor emphasized the opportunity available now to take out not only all the missiles, but also all the Soviet medium bombers (IL-28), which were neatly lined up in the open on airbases in Cuba.

General Taylor said he was unable to explain why the IL-28 medium bombers had been left completely exposed on two airfields. The only way to explain this, he concluded, was on the ground that the Cubans and the Russians did not anticipate a U.S. air strike.

General Taylor said that the military would be prepared to live with a 24-hour advance notice or grace period if such advance notice was worthwhile politically. The President expressed his doubt that any notice beyond 7 hours had any political value.

General Taylor argued that a blockade would not solve our problem or end the Cuban missile threat. He said that eventually we would have to use military force, and if we waited, the use of military force would be much more costly.

General Taylor summarized the military actions already under way, including the quiet reinforcement of Guantanamo by infiltrating marines and the positioning of ships to remove U.S. dependents from Guantanamo on extremely short notice.

General Taylor repeated his recommendation that any air strike in Cuba included attacks on the MIGs and medium bombers.

## Dean Rusk, Secretary of State

Secretary Rusk asked General Taylor whether we dared to attack operational strategic missile sites in Cuba.

Secretary Rusk said that a blockade would seriously affect the Cuban missile capability in that the Soviets would be unable to deploy any missiles to Cuba in addition to those now there.

Secretary Rusk said he hesitated to ask the question but he wondered whether these planes were decoys. He also wondered whether the Russians were trying to entice us into a trap. Secretary McNamara stated his strong doubt that these planes were decoys.

Secretary Rusk doubted that a delay of 24 hours in initiating an air strike was of any value. He said he now favored proceeding on the blockade track.

Secretary Rusk referred to an air strike as “chapter two.” He did not think we should initiate such a strike because of the risk of escalating actions leading to general war. He doubted that we should act without consulting with our allies. He said a sudden air strike had no support in the law or morality, and therefore, must be ruled out. Reading from notes, he urged that we start the blockade and only go on to an air attack when we know the reaction of the Russians and of our allies.

Secretary Rusk suggested that our objective was an immediate freeze of the strategic missile capability in Cuba to be inspected by UN observation teams stationed at the missile sites. He referred to our bases in Turkey, Spain, and Greece as being involved in any negotiation covering foreign bases. He said a UN group might be sent to Cuba to reassure those who might fear that the United States was planning an invasion.

Secretary Rusk recommended that a blockade not be instituted before Monday in order to provide the time required to consult our allies.

Secretary Rusk thought that POL should not be included now because such a decision would break down the distinction that we want to make between elimination of strategic missiles and the downfall of the Castro government. Secretary Rusk repeated his view that our objective at this time is to destroy the offensive capability of the missiles in Cuba, not to overthrow Castro!

Secretary Rusk called attention to the problem involved in referring to our action as a blockade. He preferred the use of the word “quarantine.”

## John McCone, CIA Director

Director McCone added that the Russians would not have sent 100 shiploads of equipment to Cuba solely to play a “trick.” General Taylor returned to the point he had made earlier, namely, that if we do not destroy the missiles and the bombers, we will have to change our entire military way of dealing with external threats.

Director McCone stated his opposition to an air strike, but admitted that in his view a blockade was not enough. He argued that we should institute the blockade and tell the Russians that if the missiles were not dismantled within 72 hours, the United States would destroy the missiles by air attack. He called attention to the risk involved in a long drawn-out period during which the Cubans could, at will, launch the missiles against the United States.

At this point, Director McCone acknowledged that we did not know positively that nuclear warheads for the missiles deployed had actually arrived in Cuba. Although we had evidence of the construction of storage places for nuclear weapons, such weapons may not yet have been sent to Cuba.

## Theodore Sorenson, White House Special Counsel

Mr. Sorensen said he did not agree with the Attorney General or with General Taylor that this was our last chance. He said a missile buildup would end if, as everyone seemed to agree, the Russians would not use force to penetrate the U.S. blockade.

## Robert Kennedy, Attorney General

The Attorney General returned to the point made by General Taylor—i.e. that now is the last chance we will have to destroy Castro and the Soviet missiles deployed in Cuba.

The Attorney General said that in his opinion a combination of the blockade route and the air strike route was very attractive to him. He felt we should first institute the blockade. In the event that the Soviets continued to build up the missile capability in Cuba, then we should inform the Russians that we would destroy the missiles, the launchers, and the missile sites. He said he favored a short wait during which time the Russians could react to the blockade. If the Russians did not halt developing the missile capability, then we would proceed to make an air strike. The advantage of proceeding in this way, he added, was that we would get away from the Pearl Harbor surprise attack aspect of the air strike route.

The Attorney General thought we should convey our firm intentions to the Russians clearly and suggested that we might tell the Russians that we were turning over nuclear weapons and missiles to the West Germans.

The Attorney General said we could implement a blockade very quickly and prepare for an air strike to be launched later if we so decided.

## George Ball, Under Secretary of State

Under Secretary Ball said that if an effective blockade was established, it was possible that our photographic intelligence would reveal that there were no nuclear warheads in Cuba; hence, none of the missiles now there could be made operational.

Mr. Ball made the point that we did not institute a blockade in July because we did not then know of the existence of the strategic missiles in Cuba.

Under Secretary Ball expressed his view that a blockade should include all shipments of POL to Cuba.

## Douglas Dillon, Secretary of the Treasury

Secretary Dillon mentioned 72 hours as the time between instituting the blockade and initiating an air strike in the event we receive no response to our initial action.

Secretary Dillon said that the existence of strategic missiles in Cuba was, in his opinion, not negotiable. He believed that any effort to negotiate the removal of the missiles would involve a price so high that the United States could not accept it. If the missiles are not removed or eliminated, he continued, the United States will lose all of its friends in Latin America, who will become convinced that our fear is such that we cannot act. He admitted that the limited use of force involved in a blockade would make the military task much harder and would involve the great danger of the Cubans launching of these missiles.

Secretary Dillon called attention to the fact that even if the Russians agreed to dismantle the missiles now in Cuba, continuing inspection would be required to ensure that the missiles were not again made ready.

## Adlai Stevenson, U.S. Ambassador to the UN

Ambassador Stevenson stated his flat opposition to a surprise air strike, which he felt would ultimately lead to a U.S. invasion of Cuba. He supported the institution of the blockade and predicted that such action would reduce the chance of Soviet retaliation of a nature that would inevitably escalate. In his view, our aim is to end the existing missile threat in Cuba without casualties and without escalation. He urged that we offer the Russians a settlement involving the withdrawal of our missiles from Turkey and our evacuation of Guantanamo base.

Ambassador Stevenson reiterated his belief that we must be more forthcoming about giving up our missile bases in Turkey and Italy. He again stated his belief that the present situation required that we offer to give up such bases in order to induce the Russians to remove the strategic missiles from Cuba.

## Llewellyn Thompson, Ambassador-at-Large

Ambassador Thompson stated his view that our first action should be the institution of a blockade. Following this action, he thought we should launch an air strike to destroy the missiles and sites, after giving sufficient warning so that Russian nationals could leave the area to be attacked.

**Teacher Resource 3.2.4**

# Rubric: Cuban Missile Crisis Essay

*Student Name(s):* _____ *Date:* _____

| | Exemplary | Solid | Developing | Needs Attention |
|---|---|---|---|---|
| Contributions | The student routinely provides useful ideas when participating in a group or in class discussion. | The student usually provides useful ideas when participating in a group or in class discussion. | The student sometimes provides useful ideas when participating in a group or in class discussion. | The student rarely provides useful ideas when participating in a group or in class discussion. |
| Attitude | The student is never publicly critical of others' work and always has a positive attitude. | The student is rarely publicly critical of others' work and often has a positive attitude. | The student is sometimes publicly critical of others' work and sometimes has a negative attitude. | The student is often publicly critical of others' work and often has a negative attitude. |
| Sharing Work Responsibility | Group members can always count on this person to do his or her share. | Group members can usually count on this person to do his or her share. | Group members must sometimes prompt this person to do his or her share. | Group members can rarely count on this person to do his or her share. |
| Worksheet Content | The worksheet is finished. All sentences are complete with no grammatical or spelling errors. | The worksheet is finished. Most sentences are complete, but there are one to two grammatical or spelling errors. | The worksheet is only partially finished. There are some incomplete sentences and/or three to four grammatical or spelling errors. | The worksheet is only partially finished. There are many incomplete sentences and/or five or more grammatical or spelling errors. |

AOE POE Integrated Curriculum Unit: Bombs Away

# Lesson 3.3

# Principles of Engineering

# You Sunk My Battleship

In this lesson, students will apply their knowledge of trajectory motion to build, calibrate, and use a ballistic device capable of launching ping pong balls that can hit accurately hit target between a 1 to 5 meter range. Students will be building the ballistic device that they normally build for Principles of Engineering Lesson 8.1a, except that they will mount their ballistic device onto a 3' x 1' base, in addition to the normal 1' x 1' base.

This lesson is expected to take at least six class periods.

## Lesson Framework

### Learning Objectives

Each student will:

- Design and build a ballistic device using the PLTW design process.
- Research different possible designs for constructing a homemade ballistic device.
- Calibrate the device for accurate use.
- Calculate the velocity of the launched object based on the distance traveled.

### Academic Standards

- Students will develop an understanding of the characteristics and scope of technology. (ITEA Standard for Technological Literacy, Standard 1)
- Students will develop an understanding of the core concepts of technology. (ITEA Standard for Technological Literacy, Standard 2)
- Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study. (ITEA Standard for Technological Literacy, Standard 3)
- Students will develop abilities to apply the design process. (ITEA Standard for Technological Literacy, Standard 11)

## Assessment

| Assessment Product | Assessment Criteria |
|---|---|
| BD Project (Ballistic device mounted on the "battleship") | Teacher Resource 3.3.2—Rubric: BD Project |
| Presentation about project including flier | Teacher Resource 3.3.3—Rubric: BD Project Reporting |

## Prerequisites

- Working knowledge of the principles of kinematics
- Working knowledge of the calculation of trajectory motion equations
- Working knowledge of the PLTW design process

# Instructional Materials

## Teacher Resources

- Teacher Resource 3.3.1—Activity: Battleship Competition
- Teacher Resource 3.3.2—Rubric: BD Project
- Teacher Resource 3.3.3—Rubric: BD Project Reporting

## Student Resources

- Student Resource 3.3.1—Design Brief: BD Project

## Equipment and Supplies

- Scrap and recycled materials
- Ping pong balls
- 1' x 3' boards (plywood or particle board)
- Tape measure
- Computer lab with Microsoft Excel
- Room with 25' x 25' of open space

# Lesson Steps

| Step | Min. | Activity |
|---|---|---|
| | | **CLASS PERIOD 1** |
| **1** | **10** | **Introduction: BD Project**<br>Pass out the BD Project design brief (Student Resource 3.3.1) and explain the purpose and constraints of the project. Give students time to read through the design brief on their own and to ask any questions. If possible, show some examples from previous years. |
| **2** | **varies** | **Design Process: Ballistic Devices**<br>Instruct students to follow the PLTW design process to complete the project. Students should research at least four different examples of ballistic devices before settling on their own design. Either give them time to do this in class or have them conduct the research as homework and share it with the class the next day.<br>Have students make several sketches in their engineering notebook and take notes on any advantages or disadvantages of the design. Remind students that they need to build the project out of “found” materials, so they should start assembling possible building materials as soon as possible. Their final design should include measurements. Check each design to ensure that it fulfills the design constraints before allowing students to move ahead with construction. |
| | | **CLASS PERIOD 2** |
| **3** | **varies** | **Construction: Ballistic Device**<br>Give students at least a day in class to work on the construction of the device itself. Remind students that the device needs to fit on a 1' x 1' base (which will be mounted in turn on a 3' x 1' piece). Plywood or particleboards are good, inexpensive materials to use for bases. Warehouse home improvement stores will often cut boards to the appropriate size for a nominal fee if you don’t have the capacity to cut wood at the school. The 3' x 1' base will be the “battleship” on which their devices will be mounted. Students will be aiming and firing their devices at each other’s battleships, along with aiming for the 5-gallon bucket used in the original POE lesson. |
| | | **CLASS PERIOD 3** |
| **4** | **50** | **Performance Testing: Ballistic Devices**<br>Provide a day of class time for students to conduct the standard performance testing described in POE lesson 8.1a. Have students test their device with a set of at least 10 firing angles and have them record the range. Ask students to calculate a range curve using the Excel spreadsheet from Lesson 1.5. |

| Step | Min. | Activity |
|---|---|---|
| | | After students have finished their performance testing, instruct them to begin work on their performance sheet (three-fold flier) described on the design brief, as well as work on the presentation based on the performance information. You may provide more time for students to finish this assignment in class or assign it for homework. |
| | | **CLASS PERIOD 4** |
| **5** | **50** | **Presentations: Ballistic Device Performance**<br>Give each group 5 minutes to demonstrate how their device operates and present the information from their performance sheet. Use the BD Project rubric (Teacher Resource 3.3.2) for assessing their performance.<br>After they have made their presentations, have students vote on the “best” device. Allow the class to decide how they define “best”; they may not vote for their own device. |
| | | **CLASS PERIODS 5 AND 6** |
| **6** | **100** | **Competition: Battleships**<br>After students have finished testing and calibrating their devices, assess them on the final test, using the BD Project Reporting rubric (Teacher Resource 3.3.3).<br>A fun way to culminate the lesson is for students to compete against each other. Clear out and mark a grid with 1' squares in a large space (e.g., cafeteria, hallway, gym, middle of your room). If possible, it may be easiest to use an area that is already covered with square tiles. This will serve as the “sea of battle.” A space of 25' x 25' is a good size. You may need to adjust the way you set up the competition based on the amount of space you have available. With a smaller space, students can compete two against two rather than three against three. In a larger space, have larger teams compete against each other. Allow each side to alternately place one battleship at a time on the grid (no diagonals). Teams can flip a coin to see which side fires first. Between each round, allow each battleship to move up to five adjacent spaces, or one rotation of 90°. |

AOE POE Integrated Curriculum Unit: Bombs Away

# Lesson 3.3

# Principles of Engineering

# You Sunk My Battleship

## Student Resources

| Resource | Description |
|---|---|
| Student Resource 3.3.1 | Design Brief: BD Project |

**Student Resource 3.3.1**

# Design Brief: BD Project

## Purpose

Things move in predictable patterns. A ball thrown in the air moves in a curved path until it strikes the Earth. We can analyze where it will strike the ground if we make some basic assumptions about free-fall acceleration and if we discount the effects of wind resistance.

## Materials

- Scrap and recycled materials
- Ping-pong balls
- Tape Measure
- Excel®

## Objective

Create a device that will toss a ball accurately within a given range.

## Constraints

- Must be able to fire a projectile (to be specified by the instructor) anywhere within a 5' to 15' operating range (design adjustability into your device!).
- Must fit within a 1'x1' footprint (in “collapsed form”).
- Cannot utilize high-pressure gases or combustible materials.
- Must be constructed primarily out of materials that are “found,” not bought.
- Must be sketched in engineering journals and approved by your instructor prior to building.

## Performance Testing

After completion of final assembly and adjustment, do the following:

- Choose at least 10 firing angles that are between 10 and 80 degrees.
- For each firing angle, fire the projectile and record range.
- Perform at least three trials for each firing angle.
- Record all procedures, tables, data, etc. within engineering journals.

## Final Testing

- Must be able to land in a 5-gallon bucket (the target) at a location specified by your instructor on the day of the test (and within the operating range).
- Each team will have three tries to hit the target.

## Battleship Competition

Each project will be mounted on 3' x 1' piece of plywood representing a battleship. Teams of three will compete against each other on a 25' x 25' grid. Team members will place their ship on the grid one at a time. Once each ship has been placed on the grid, the competition begins. Each round has two phases: movement and firing. In movement, each ship may move up to 5 grid squares in any direction. In firing, each ship may choose to fire at another ship. If you're hit anywhere on the 3' x 1' ship (including the project itself), you've been sunk and are out. The winning team is the first to sink all the battleships on the opposing team.

## Performance Sheet

Each team must create a three-fold flier that includes the following:

- Names of the device team members
- Sketch or drawing of the device
- Picture (digital image)
- Description of how it operates
- Summary of testing data and procedures
- Graph of firing angle versus range
- Other important information

## Presentation

Each team must create and deliver a 5-minute presentation to the class.

- The presentation must include:
    - All information contained in the performance sheet
    - A demonstration of the operation of the device
- All team members must contribute to the presentation.
- After all presentations are given, the class will vote on the "best" device; teams may not vote for their own device. The team that has been voted "best" will receive bonus points.

AOE POE Integrated Curriculum Unit: Bombs Away

# Lesson 3.3

# Principles of Engineering

# You Sunk My Battleship

## Teacher Resources

| Resource | Description |
|---|---|
| Teacher Resource 3.3.1 | Activity: Battleship Competition |
| Teacher Resource 3.3.2 | Rubric: BD Project |
| Teacher Resource 3.3.3 | Rubric: BD Project Reporting |

**Teacher Resource 3.3.1**

# Activity: Battleship Competition

## Directions for the Class

*Prepare a 25' x 25' grid in a large clear area (outside, cafeteria, gym, your classroom). It's easiest if you can find a room that has 1-square foot tiles. Divide the class into groups of three. One group of three will compete against another group of three. Flip a coin to see which side begins first and then alternate. Battleships must be placed in line with the grid (no diagonals), just like in a board game.*

*Play as many rounds as necessary until the game is over.*

- *Each round of the game as two phases: movement and firing.*
- *During movement, one at a time, beginning with the player who placed first, each ship may move up to 5 tiles in any direction or may rotate its entire movement.*
- *During firing, each ship may take one shot in the same order as during movement.*

*The game is over when all of one team's ships are sunk.*

**Teacher Resource 3.3.2**

# Rubric: BD Project

*Student Name(s):* _____ *Date:* _____

## Preliminary Work and Record Keeping–Individual Grade

| | Non-existent | F Level Poor | D Level Fair | C Level | B Level Good | A Level Excellent |
|---|---|---|---|---|---|---|
| Sketch of Device | 0 | 6 | 7 | 8 | 9 | 10 |
| Testing Procedures | 0 | 6 | 7 | 8 | 9 | 10 |
| Test Data | 0 | 6 | 7 | 8 | 9 | 10 |
| Outline of Flier | 0 | 6 | 7 | 8 | 9 | 10 |
| Evidence of Experimentation | 0 | 6 | 7 | 8 | 9 | 10 |

Total Points Earned: _____ / 50

## Final Testing–Team Grade

| | Doesn't Hit Target | Hits Target on Third Try | Hits Target on Second Try | Hits Target on First Try |
|---|---|---|---|---|
| Accuracy | 75 | 95 | 100 | 110 |

Total Points Earned: _____ / 100

**Teacher Resource 3.3.3**

# Rubric: BD Project Reporting

## Three-Fold Flier–Team Grade

| | Non-existent | F Level Poor | D Level Fair | C Level | B Level Good | A Level Excellent |
|---|---|---|---|---|---|---|
| Device/Team Members' Names | 0 | 3 | 3.5 | 4 | 4.5 | 5 |
| Sketch/Drawing | 0 | 12 | 14 | 16 | 18 | 20 |
| Picture | 0 | 6 | 7 | 8 | 9 | 10 |
| Description | 0 | 6 | 7 | 8 | 9 | 10 |
| Testing Summary | 0 | 12 | 14 | 16 | 18 | 20 |
| Graph | 0 | 12 | 14 | 16 | 18 | 20 |
| Additional Info | 0 | 6 | 7 | 8 | 9 | 10 |
| Creativity/Professionalism | 0 | 9 | 10 | 12 | 13 | 15 |

Total Points Earned: _____ / 100

## Presentation

| | Non-existent | F Level Poor | D Level Fair | C Level | B Level Good | A Level Excellent |
|---|---|---|---|---|---|---|
| Follows Logical order/Format | 0 | 6 | 7 | 8 | 9 | 10 |
| Flier Explanation | 0 | 6 | 7 | 8 | 9 | 10 |
| Demonstration | 0 | 6 | 7 | 8 | 9 | 10 |
| Responds Well/ Appropriately to Questions | 0 | 6 | 7 | 8 | 9 | 10 |
| Each Team Member Contributes | 0 | | | | | 10 |

Total Points Earned: _____ / 50

Comments: