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## Submarine-Launched Ballistic Missile (SLBM) Simulation

This is an outdoor activity

Grade Level:  
9-12

Objectives:

Students will be able to:

- Describe in writing the difference among velocity, acceleration, and momentum
- Calculate velocity, acceleration, and momentum
- Simulate the launch of an underwater missile
- Identify in writing two variables affecting a launch

**California Science Standard:**

Motion and Forces

1. Newton's laws predict the motion of most objects.
  - a. Students know how to solve problems that involve constant speed and average speed.

Investigation & Experimentation

Scientific progress is made by asking meaningful questions and conducting careful investigations.

1. Select and use appropriate tools and technology (e.g. meter stick, graphing calculators, video camera) to perform tests, collect data, analyze relationships, and display data.
  - a. Select and use appropriate tools and technology collect data, analyze relationships, and display data.
  - d. Formulate explanations by using logic and evidence.

**National Board for Professional Teachers Standards: Science**

Standard I: Understanding Students

Accomplished Adolescence and Young Adulthood/Science teachers know how students learn, know their students as individuals, and determine students' understandings of science as well as their individual learning backgrounds.

Standard II: Understanding Science

Accomplished Adolescence and Young Adulthood/Science teachers have a broad and current knowledge of science and science education, along with in-depth knowledge of one of the sub-fields of science, which they use to set important and appropriate learning goals.

Standard IV: Engaging the Science Learner

Accomplished Adolescence and Young Adulthood/Science teachers spark student interest in science and promote active and sustained learning, so all students achieve meaningful and demonstrable growth toward learning goals.

Standard V: Sustaining a Learning Environment

Accomplished Adolescence and Young Adulthood/Science teachers create safe, supportive, and stimulating learning environments that foster high expectations for each student's successful science learning and in which students experience and incorporate the values inherent in the practice of science.

Classroom Correlation:

Although the focus of my fellowship is e-learning, the department in which my tasks are performed is Fleet Ballistic Missile (FBM) of the Space System Division. FBM is responsible for designing, developing, manufacturing and maintaining the underwater launched missile. The proposed lesson plan will simulate the launching of a missile from a submarine.

Equipment/Supplies:

- 2-digital video camera (preferably with shutter adjustment),
- 2-video cassette tape
- 3- portable lights (optional)
- 2-191L aquarium (121cmx51cmx31cm)
- 1-32 cm pvc pipe (launch tube) with 2.54 cm internal diameter (construct 2 launcher)
- 1-520cm wooden dowel of 2.54cm diameter (construct 32 missiles)
- 1 box of rubber band
- 1 roll of wax paper
- 1 roll of butcher paper
- 6-varying colored permanent markers
- 1 water hose and access to spout
- 2-plastic lawn shut-off valve with lever
- 2-plastic hose couplings
- 2-male PVC adapter (1.9cm x 2.54cm)
- 2-1.9cm threaded PVC street elbow
- 2-183cm male-female connector tube
- sandpaper

Engage:

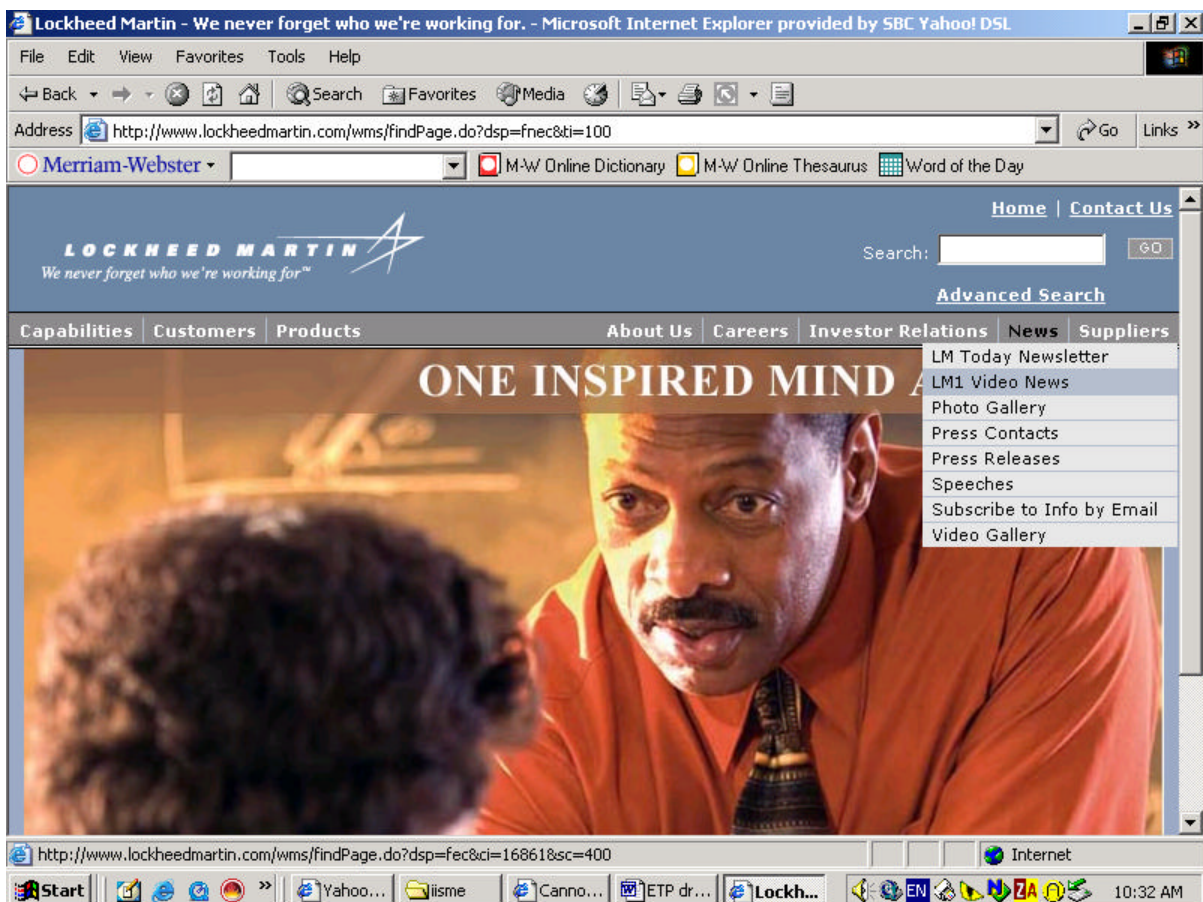
A) The instructor provides an anecdotal story about motion, talking about a spacecraft, a race, a car, a bottle rocket (firecracker) or presents the following.  
Lockheed Martin developed a new missile in the 1990s called Trident II also known as D5. This missile is launched from a nuclear submarine at a specific depth. The initial propulsion of the missile is by expanding nitrogenous gas. The missile breaks through a fibrous cover and travels through ocean water before the first stage engine ignites. It next flies for about a minute after which the first stage falls off. The second stage ignites and propels the vehicle for another minute. The second and third stages continue the boost

phase beyond the atmosphere. From here, the weapons travel through space and reenter the atmosphere to reach its target.

B) The teacher then displays 3 rhetorical questions, which are to stimulate the students to think about motion:

- 1) What do the videos have in common?
- 2) How are the videos related to science?
- 3) What aspects of Physics did you notice in the videos?

C) The educator instructs the students to view from Lockheed Martin's website the launching of vehicles. Navigation path: <http://www.lockheedmartin.com> → place mouse pointer over "NEWS", click on "LM1 Video News" → then "Launch/last Titan at Cape"



Explore:

DAY 1

A) Students choose a partner

B) Students work in pairs to answer questions from Trident II (D5) worksheet. The questions are based on information at:

<http://www.chinfo.navy.mil/navpalib/factfile/missiles/wep-d5.html> and

<http://www.fas.org/nuke/guide/usa/slbm/d-5.htm>. The pairs will collaborate with another pair to discuss the answers. The teacher will request a partnership to provide

the answers to the class. One person will read the answers while the other writes the information on the board. The teacher will facilitate a discussion to derive any challenging answers.

C) The educator informs the students they will construct a missile model to simulate an underwater launch of a missile.

D) The students are given a 15cm wooden cylinder (the missile) and piece of sandpaper to shape the nose of their missile. Half the class will develop coned shape noses (see below) while the other half will develop rounded shaped noses (see below). The choice is left to the partners. The sanding will begin in class and continue for home work. They will use the colored permanent markers to indicate the 4 stages of the missile as shown in the drawing at <http://www.fas.org/nuke/guide/usa/slbn/d-5.htm>

\* Ensure the students are sanding the sides to develop the shapes. Do not decrease the missile's height.

coned



rounded



\*Preparation:

**By teacher:** Cut the 520cm wooden cylinder into 32 16cm long pieces. These represent the missiles. Next cut the 32cm PVC pipe into 2-16cm long launch tubes. Set up video cameras, one to record the motion in the water and the other to record the motion in the air

**By two students:** mark off 5cm intervals on two difference pieces of butcher paper that is 244cm long, and then tape one behind the each aquarium

DAY 2-3

D) The teacher will set up the 2 aquaria; use the butcher paper to develop a grid to identify the different positions of the missile, and build the launcher.

1. fill one aquarium with water that is 32cm high, representing 1 atmospheric pressure and the second that is 48cm high, representing 2 atmospheric pressure
2. construct the launcher
  - i. rotate the PVC adapter (a) to the PVC street elbow (b)
  - ii. twist the PVC street elbow (b) into the plastic hose coupling (c)

- iii. turn the plastic hose coupling (c) onto the connector tube (d)
  - iv. screw the connector tube (d) to the shut-off valve (e)
  - v. push the launch tube (f) into the PVC adapter (a)
3. repeat i-v to make the second launcher
  4. place missile in launch tube
  5. place 5cm<sup>2</sup> wax paper over the launcher tube's hole
  6. secure the wax paper with rubber band



(a) PVC adapter



(b) PVC street elbow



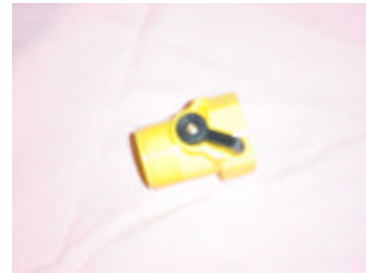
(f) PVC tube



(c) Plastic hose coupling



(d) Male-female connector tube



(e) Lawn shut off valve



(g) Missile (wooden dowel)

\*NOTE: The plastic hose coupling, male-female connector tube, lawn shut off valve, PVC adapter, and PVC street elbow may be purchased at Orchard Supply Hard while the PVC tube and missile (dowel) may be bought at Home Depot for a total of approximate \$30.00.

E) Two pairs will launch their missiles from the two different aquaria. On a log sheet, each person will write her/his name. The log is used later to identify the order to review the tape in order to obtain the data. Before the launches, each person's name, and missile nose shape is introduced while being video taped. Each missile is launched 3 three times, which are recorded by video. The partner will record the introduction and launches, under teacher supervision. When the trials are complete the pairs will return to class

F) The remainder of the class is divided into two groups: 1) will listen to the textbook publisher's CD about motion and take notes, which indicates questions 2) will read the textbook on motion and take notes, which indicates questions. Upon complete of either activity, the students will form groups of 4 to answer the questions from their note-taking task. All unanswered questions are posed to the entire class, with the teacher as a facilitator.

## **ELABORATE**

DAY 4-5

G) The teacher demonstrates how to obtain the data from the videotape to calculate: velocity, acceleration, and momentum. Then, each student will review the tape to obtain his or her own data. The teacher will inform the students of how to determine distance and time. Afterwards, the students will complete the Missile Activity Worksheet.

The time calculation is based on the shutter speed of the video camera, for example 1/250. The student will count the number of frames from the when the missile is seen until it reaches a desired position, like the water surface. If there are 190 frames, this number is divided by 250 to obtain time, ( $190/250 = 0.76$  sec). The frames are counted while in the pause mode.

H) The teacher facilitates a discuss to answer lingering questions, to explain terms and concepts

## **EVALUATE**

I) The post-test is given

## **EXTENSION**

The student may graph the time vs. distance and derive the slope. In addition, missile launched only in air can be compared to those submerged launches.

## MISSILE ACTIVITY WORKSHEET

1. Hypothesize which missile has the greatest velocity traveling in the water, and then provide a brief explanation for your answer (one sentence).
2. Predict which substance (water or air) will have the greatest missile velocity, then provide a brief explanation for your answer (one sentence).
3. Write the procedure to determine distance.
4. Write the procedure to determine time.
5. Calculate the velocity of the missile in the water ( $v = d/t$ )
6. Calculate the velocity of the missile when the nose is 10 cm out of the water. ( $v = d/t$ )
7. Derive missile acceleration in the water ( $a = \Delta v/\Delta t$ ).
8. Derive potential missile acceleration in the air ( $a = \Delta v/\Delta t$ ).
9. Derive potential missile momentum in the air ( $p = mv$ ).
10. Explain why acceleration and momentum are potential values.

This table is used to enter the data obtained from the missile launches

coned nose shape	Time (s)	1 atmosphere	2 atmosphere
Trial 1 height (cm)			
Trial 2 height (cm)			
Trial 3 height (cm)			

This table is used to enter the data obtained from the missile launches

rounded nose shape	Time (s)	1 atmosphere	2 atmosphere
Trial 1 height (cm)			
Trial 2 height (cm)			
Trial 3 height (cm)			

## TRIDENT II (D5) WORKSHEET

Answer the following questions on you binder paper using complete sentences. In addition, **show ALL your calculations**.

1. How long is a Trident II in inches and decameters?
2. What is the diameter in decimeters of a D5?
3. Calculate the weight differential of the D5 and C3.
4. Identify in hectometers and meters the minimum range of a D5.
5. Explain the difference between the stages of a C3 and D5.
6. Sketch 2 diagrams (pictures) of a D5, one showing the patterns of the missile and the other indicating: aerospike, nose fairing, second stage, interstage, and first stage. Use <http://www.fas.org/nuke/guide/usa/slbm/d-5.htm> to complete.
7. Describe an unexpected feature about the missile (hint there's something missing).

**PRE-TEST**

- 1) Define the following terms in words and by formulate:
  - a. velocity
  - b. acceleration
  - c. momentum
- 2) Explain the difference between velocity and acceleration.
- 3) Provide specific an example of how momentum will:
  - a. increase
  
  - b. decrease
- 4) A car is filmed on a video camera travel at 100 meters for 5 seconds. Calculate the car's velocity.
- 5) The velocity of a missile is 1200 m/s and travels for 20 s. How far has the missile traveled?

**POST-TEST**

- 1) Define the following terms in words and by formulate:
  - a. velocity
  - b. acceleration
  - c. momentum
- 2) Explain the difference between velocity and acceleration.
- 3) Provide specific an example of how momentum will:
  - a. increase
  
  - b. decrease
- 4) A car is filmed on a video camera travel at 100 meters for 5 seconds. Calculate the car's velocity.
- 5) The velocity of a missile is 1200 m/s and travels for 20 s. How far has the missile traveled?
- 6) Identify 2 variables from the Missile Activity
- 7) Briefly explain how the nose shape may affect a missile's motion.

**STUDENT EVALUATION**

- 1) How do I complete the activity
  
- 2) What instructions are clear
  
- 3) Which instructions are unclear
  
- 4) What do I do to resolve the unclear instruction
  
- 5) Identify the objectives of the activity
  
- 6) Explain the concepts learned from the activity
  
- 7) Describe how you may use the information learned
  
- 8) How is the activity related to science (Which is the related science)

## **SIMULATION EVALUATION**

- 1) What are the most interesting parts
  
- 2) What are the least interesting parts
  
- 3) What did you expect to learn from the activity
  
- 4) What did you learn from the activity
  
- 5) What do you remember from the activity
  
- 6) Which parts did I complete
  
- 7) Which parts I did not complete
  
- 8) Which section were difficult to understand
  
- 9) How can this activity be improved