RADAR:
Doppler Effect in Action

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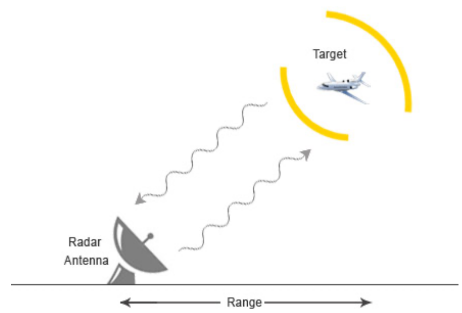
Name: ___________________________________

At any given moment there are about 5,000 commercial airplanes in the sky over the United States. Those who live close to an airport may see some of these planes, but many fly above clouds and beyond our field of vision. Air traffic controllers, ATCs, based in traffic control centers and at each airport have the responsibility of directing planes from an area of up to 200 miles wide to ensure that our crowded airspace does not result in crashes. So how do the ATCs keep track of all the planes, ensuring minimum distances between each, without being able to see hundreds of miles away? Radar!

Radar, which stands for radio detection and ranging, uses electromagnetic waves to "see" what the eye cannot. The electromagnetic waves, usually radio or microwaves, sent by a transmitter near the control center are reflected by metallic objects, water, and landforms. A receiver and processor then measure the reflected wave to determine an object's location and speed. Because all electromagnetic waves, radio or microwave, travel at a constant speed, by measuring the time it takes for a signal to return, the distance of the object can be measured.



To measure the speed of an object, radar often depends on the Doppler effect. This effect is the difference between the observed frequency and the emitted frequency of a wave. By measuring the received wave that bounced off of an object and comparing it to the emitted wave that the transmitter sent, we can determine how fast an object is moving and in which direction, or its velocity.

Radar has applications outside of air traffic as well. Doppler radar can also detect water, making it an essential tool for meteorologists to see coming storm systems and to track their strength. Variations like SONAR, which uses sound, and LIDAR, which uses high-frequency light, have been used to better detect the ocean floor, forest canopies, and more.

❓ *Quick Start: What are the benefits of using RADAR for air traffic control?*

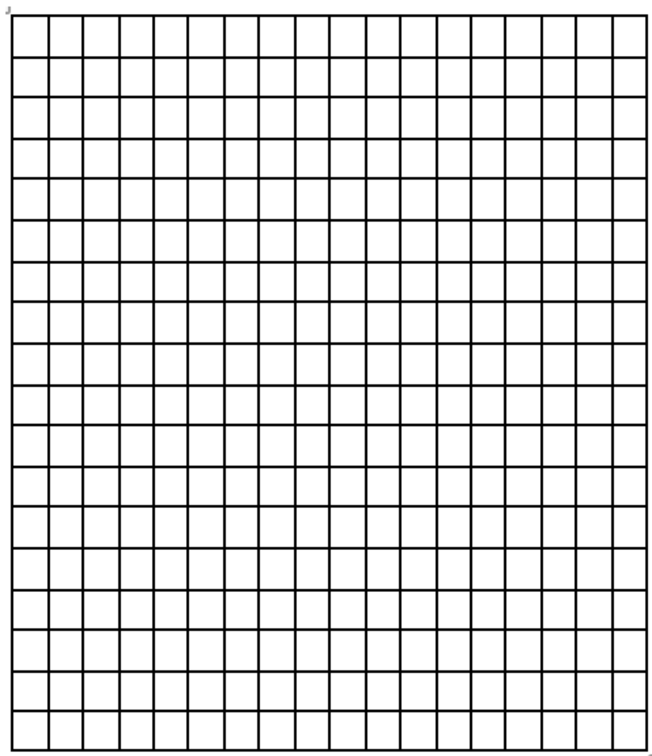
PART 1: FROM DISTANCE TO SHAPE

Inside the box at your station is a three-dimensional shape. Without looking inside the box, it will be up to you and your classmates to determine the shape that lies within using the radar setup.

Measuring Distance

1. In Table 1 below, circle the axis that you will be measuring. It can also be found on the box in front of you.
2. On the your touch display, select "Part 1", to begin collecting distance measurements.
3. Drag the sensor's cursor on the track so that the black bar aligns with 0cm on the ruler.
4. Record the distance to the closest centimeter in the table below.
5. Continue to collect distance measurements for every half-centimeter.
6. Graph your data on the graph below. *Hint: the x-axis of the graph will be the cursor placement and the y-axis will be the distance recorded.*
7. Compare your graph to that of your tablemates.

Table 1	**X-Axis**	**Y-Axis**	**Z-Axis**
Cursor Placement	*Distance (cm)*		
0 cm			
1 cm			
2 cm			
3 cm			
4 cm			
5 cm			
6 cm			
7 cm			
8 cm			
9 cm			
10 cm			
11 cm			
12 cm			
13 cm			
14 cm			
15 cm			



? *Quick Check: What shape was in your box?*

PART 2: DETECTING MOTION

Using the Doppler effect, scientists can detect not only an object's distance but also its velocity.

$$f_o = \frac{v + v_o}{v + v_s} f_s$$

f_o = observer frequency
v = speed of sound waves
v_o = observer velocity
v_s = source velocity
f_s = source emitted frequency

Determine Object's Path of Motion

1. Return to the menu screen on your touch display, press and hold the "Menu" button.
2. Once all groups at the table have returned to the menu, press the switch in the back of the box to start the object's repeated motion.
3. Place your radar cursor at the following location (determined by your axis):
    a. X- Axis: set to 8cm
    b. Y- Axis: set to 12cm
    c. Z-Axis: set to 12cm
4. Altogether, all groups at the table press the button on the touch display for "Part 2" to begin data collection.
5. Record the data in the table below. Share data with your tablemates to complete the table.

X- Axis			**Y- Axis**			**Z- Axis**		
Time (s)	*Distance (cm)*	*Velocity (cm/s)*	*Time (s)*	*Distance (cm)*	*Velocity (cm/s)*	*Time (s)*	*Distance (cm)*	*Velocity (cm/s)*

❓ *Quick Check: Use your data to predict how the object moved within the box.*

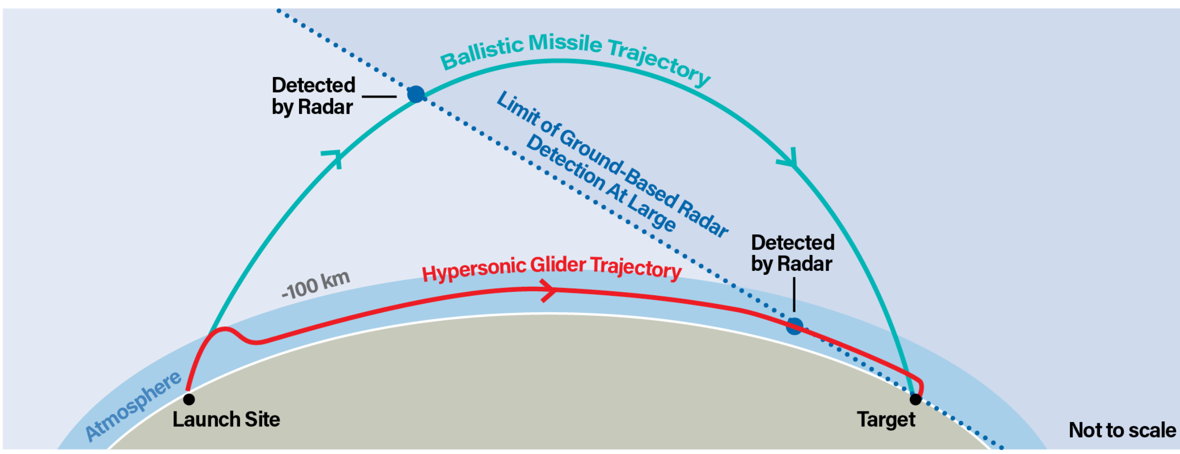
❓ *Quick Check: Was all motion detected by your equipment? If not, why?*

PART 3: CURRENT RADAR SYSTEM HURDLES

For the U.S. Department of Defense, radar can be used to detect incoming missiles so that they can be intercepted to prevent destruction and loss of life.

Radar systems can only look in a 360-degree sweep from their location on earth, a sphere. This means that RADAR detection from one system is tangential to the Earth's surface. Look at the image below then answer the following questions.

❓ *Quick Check: What is a tangent?*



https://www.airandspaceforces.com/article/enhanced-space-based-missile-tracking/

❓ *Which will the radar system detect first: a ballistic missile or a hypersonic glider?*

❓ *How could radar systems be changed to detect hypersonic gliders more effectively?*