

advanced air mobility

drones



urban air mobility

air
taxis

STEM LEARNING:

Advanced Air Mobility: Flight
Control Math 1 (Graphing)
Educator Guide

www.nasa.gov

OVERVIEW

In this lesson, students use graphing in a real-world situation to learn about geofencing. By combining coordinate systems with maps, students locate positions and specified areas. Using this information, students evaluate different routes that air taxis can take.

Objectives

Students will be able to:

- Plot points in all four quadrants of a Cartesian coordinate system
- Use points to construct lines and shapes
- Validate air taxi routes based on data

Student Prerequisite Knowledge

Before beginning this lesson, students should be familiar with:

- Plotting coordinates on a graph

Standards

CCS.MATH.CONTENT.6.NS.C.6: Understand a rational number as a point on the number line. Extend number line diagrams and coordinate axes familiar from previous grades to represent points on the line and in the plane with negative number coordinates.

Next Generation Science Standards

Cross Cutting Concepts

- Systems and system models

Science and Engineering Practices

- Developing and using models
- Analyzing and interpreting data
- Using mathematical and computational thinking
- Plotting coordinates on a graph

Materials

- Student Guides

Lesson Modifications

This lesson can be easily modified depending on student needs. More locations can be added to the graph to provide more practice. Modifying the shape of the geofenced areas can change the difficulty level of graphing them.

One version of this activity has all coordinates in quadrant 1 and another version has some coordinates in each of the four quadrants. The answers for both versions can be found in this educator guide.

Locations on Earth can all be specified using latitude and longitude. As an enrichment activity, students can research longitude and latitude using the internet or other resources. Comparing and contrasting longitude and latitude to the coordinate system in this exercise helps students further understand the real-world application of graphing while mapping. Have them determine where on Earth would be the origin in the latitude/longitude system.

Grouping Students

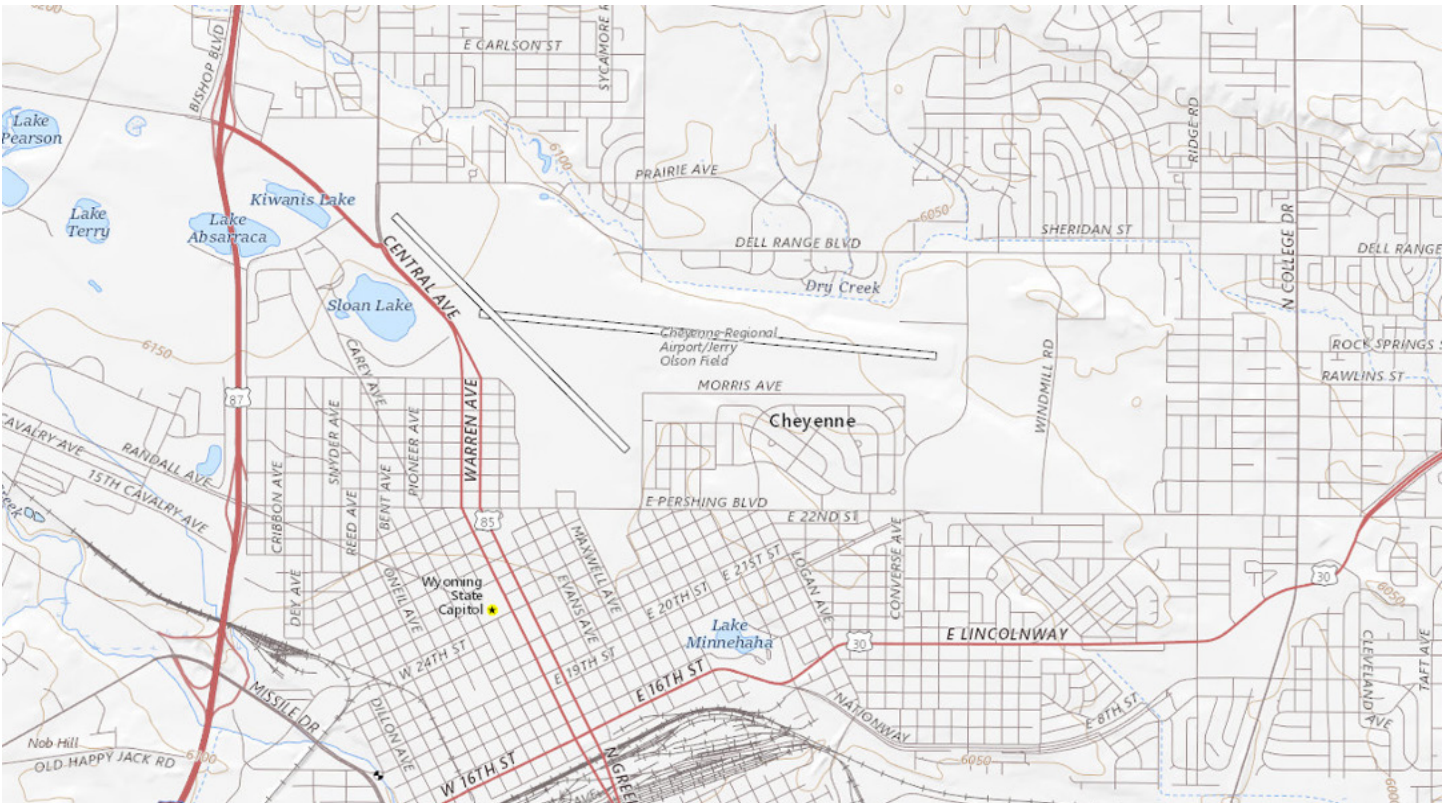
This activity is designed to be completed independently. Grouping can, however, be used if necessary. Students working in pairs can independently solve the problem and then compare answers to validate their solutions or find errors.

Steps

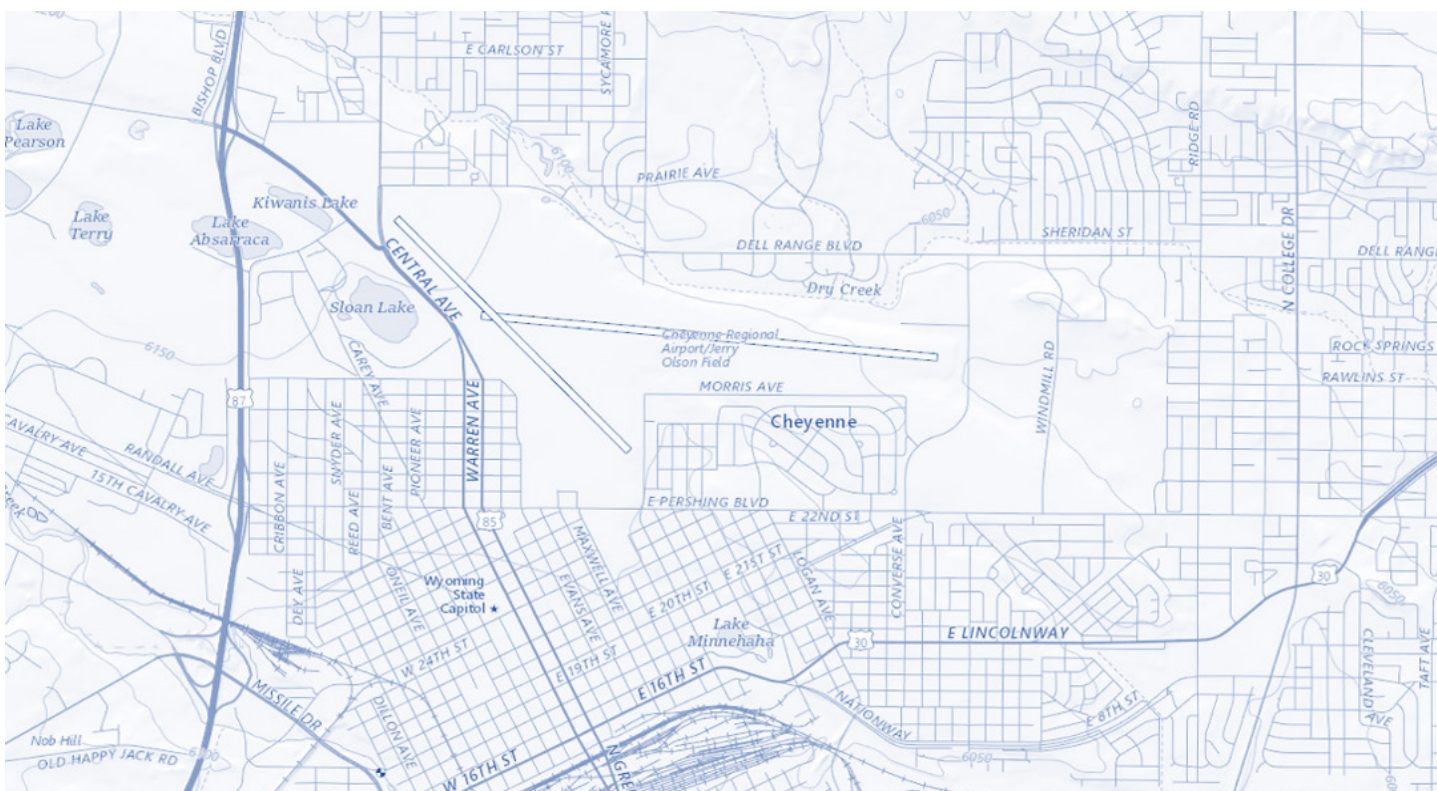
1. Show the students the NASA video about Safeguard (technology used to implement geofencing). The video is available at: <https://www.youtube.com/watch?v=0Kc01cV7vCU>.
2. Review graphing on the Cartesian coordinate system.
3. Show the map of Cheyenne, Wyoming without the grid. Discuss the function of air taxis and the dangers associated with flying in some areas, such as over the airport.
4. Show the map of Cheyenne, Wyoming with the grid. Discuss how using the grid makes it possible to specify locations because it provides a reference point.
5. Distribute the student guides and allow students to begin working.
6. Allow students to verify answers for the “Getting the Coordinates” section. (This allows students to find errors that would be compounded in the “Using the Distance Formula” section.)



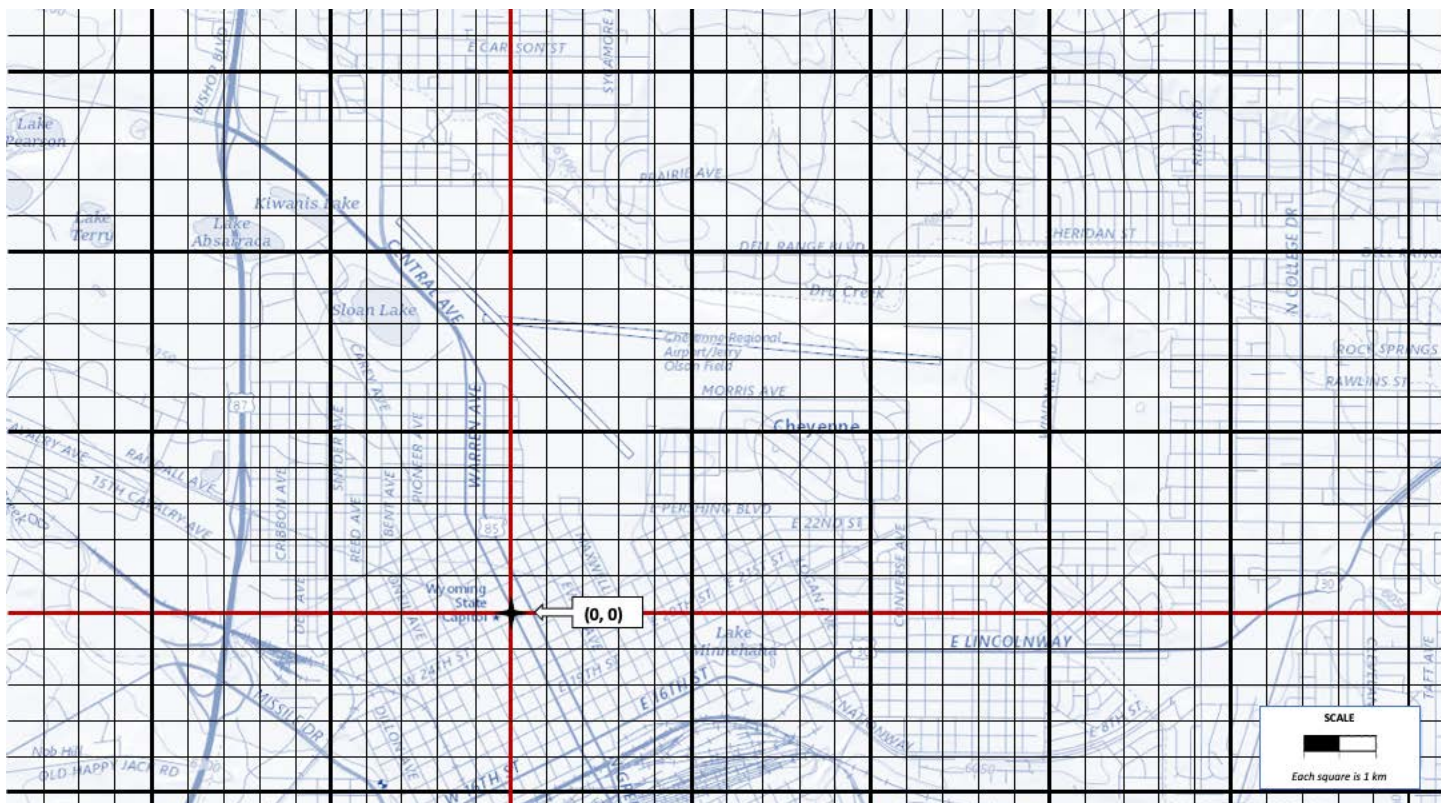
A satellite photo of Cheyenne, Wyoming. Credit: USGS.



A map of Cheyenne, Wyoming with numerous colors. Credit: USGS.



A map of Cheyenne, Wyoming that is blue and white. Credit: USGS.



A map of Cheyenne, Wyoming with a grid overlaid on it that includes the origin near the center. Credit: USGS.

ANSWERS (USING ALL FOUR QUADRANTS)

PART 1

This student guide includes a coordinate system with the origin set to correspond with the maps shown. You can also use regular graph paper to complete this activity.

1. The geofenced area around the state capitol is a 2 x 2 box. The coordinate for the corners of this box are: (1, 1), (1, -1), (-1, -1), and (-1, 1). Plot these points on the graph and connect the four points to create a box. Shade in this area.
2. Because of its runways, the geofenced area around Cheyenne Regional Airport is a bit more complicated. The coordinates for the corners of the geofenced areas are: (-4, 12), (0, 12), (0, 9), (13, 9), (13, 4), and (-4, 4). Plot these points on the graph and connect the points to show the geofenced area. Shade in this area.

The graph showing the answers is included later in this guide.

PART 2

You get a job in Cheyenne, Wyoming managing an air taxi service. Small, unmanned vehicles make up your fleet of air taxis. Your job is to determine the routes they need to fly to transport passengers around the city. In an urban setting like Cheyenne, air taxis cannot land or take off from anywhere they want. Instead **vertiports** are established throughout the city for this purpose. Vertiports are buildings from which air taxis can land and take off.

The graph showing some of the answers is included later in this guide.

1. Plot the following points and mark each with its corresponding letter. These points represent the vertiports in Cheyenne, Wyoming.

Point	X	Y
A	9	-1
B	-11	8
C	-9	-4
D	-3	-2
E	3	14
F	16	3
G	23	15

2. Your company’s headquarters are located by the vertiport represented by point A. This is where all your air taxis are housed when not in use.

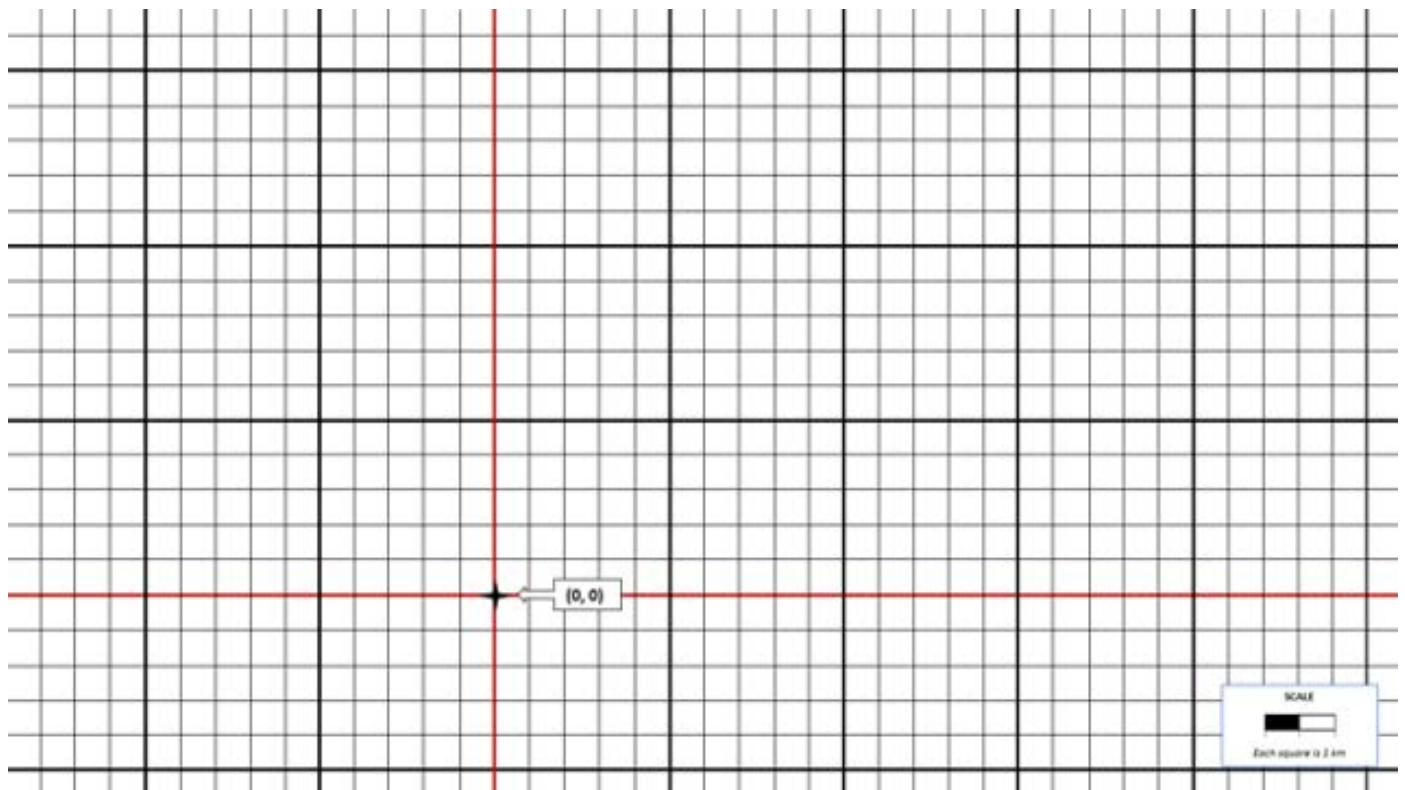
This morning, you want to send air taxis from point A to each of the other vertiports. On your graph, draw a line for each of the six paths. For each path, determine whether it can fly straight from point A to its destination without going into a geofenced area and write your answer below. Your graph should prove evidence for each.

From A to B: <u>It cannot fly straight</u>	From A to E: <u>It cannot fly straight</u>
From A to C: <u>It can fly straight</u>	From A to F: <u>It can fly straight</u>
From A to D: <u>It can fly straight</u>	From A to G: <u>It can fly straight</u>

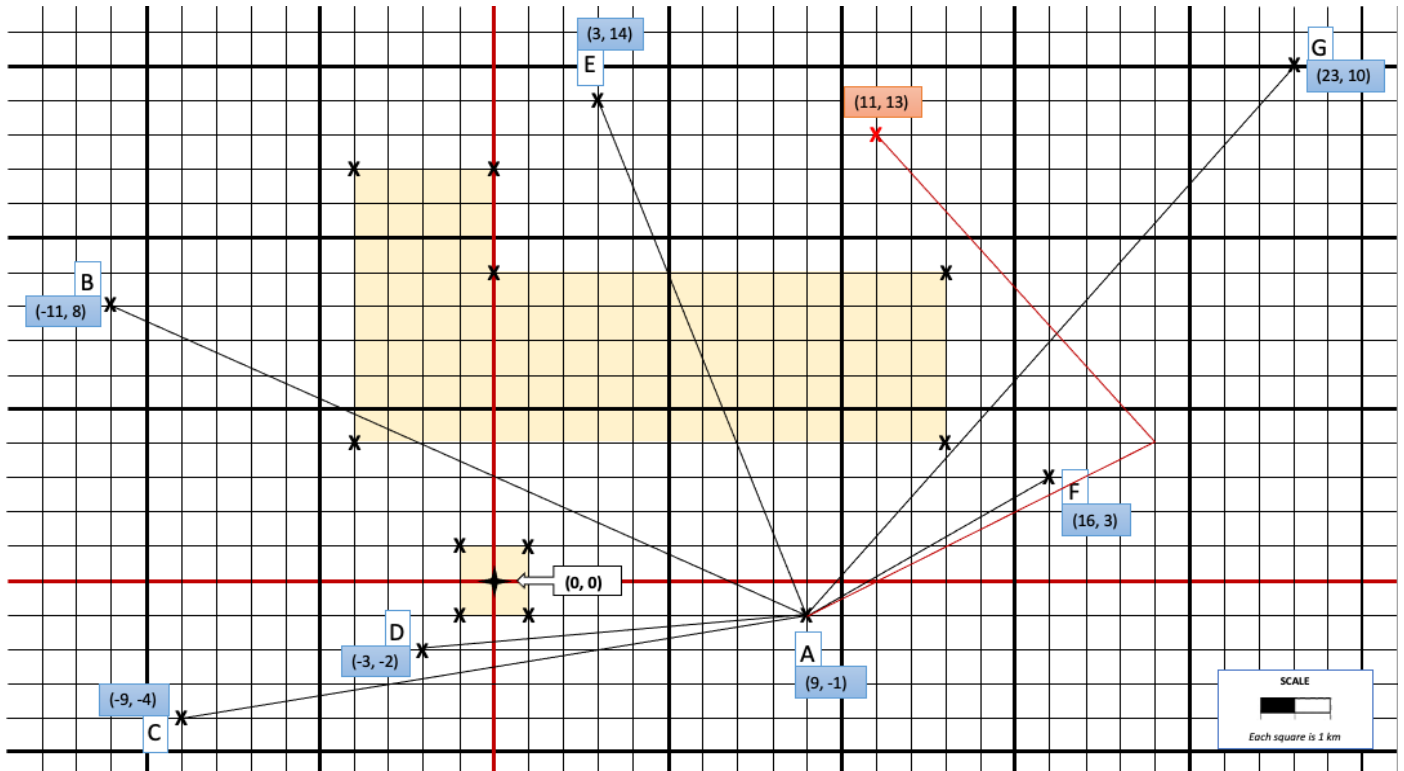
3. The city is planning on building a new vertiport at the coordinates (11, 13). Because of the geofenced area around the airport, you cannot send an air taxi straight from your headquarters to this new vertiport.

So, you decide to create a waypoint where your air taxi can turn. The air taxi should be able to fly straight from headquarters to this point and then straight from this point to the new vertiport, all without entering a geofenced area. You need to find **one point** east (to the right) of the geofenced area that could act as the waypoint. Enter the coordinates of your point below, graph it, and show both legs on the air taxi’s flightpath as evidence that the waypoint you chose met the criteria.

Coordinates of the waypoint: **There are many possible answers; the graph shows the point (19, 4) as one possible solution.**



Blank graph.



Answer Key Graph.

ANSWERS (USING ONLY QUADRANT 1)

The following can be used to complete this activity with all points in quadrant 1 of the coordinate system.

PART 1

This student guide includes a coordinate system with the origin set to correspond with the maps shown. You can also use regular graph paper to complete this activity.

1. The geofenced area around the state capitol is a 2 x 2 box. The coordinate for the corners of this box are: (12, 4), (12, 6), (14, 6), and (14, 4). Plot these points on the graph and connect the four points to create a box. Shade in this area.
2. Because of its runways, the geofenced area around Cheyenne Regional Airport is a bit more complicated. The coordinates for the corners of the geofenced areas are: (9, 17), (13, 17), (13, 14), (26, 14), (26, 9), and (9, 9). Plot these points on the graph and connect the points to show the geofenced area. Shade in this area.

The graph showing the answers is included later in this guide.

PART 2

You get a job in Cheyenne, Wyoming managing an air taxi service. Small, unmanned vehicles make up your fleet of air taxis. Your job is to determine the routes they need to fly to transport passengers around the city. In an urban setting like Cheyenne, air taxis cannot land or take off from anywhere they want. Instead **vertiports** are established throughout the city for this purpose. Vertiports are buildings from which air taxis can land and take off.

The graph showing some of the answers is included later in this guide.

1. Plot the following points and mark each with its corresponding letter. These points represent the vertiports in Cheyenne, Wyoming.

Point	X	Y
A	22	4
B	2	4
C	4	1
D	11	3
E	16	19
F	29	8
G	36	20

2. Your company's headquarters are located by the vertiport represented by point A. This is where all your air taxis are housed when not in use.

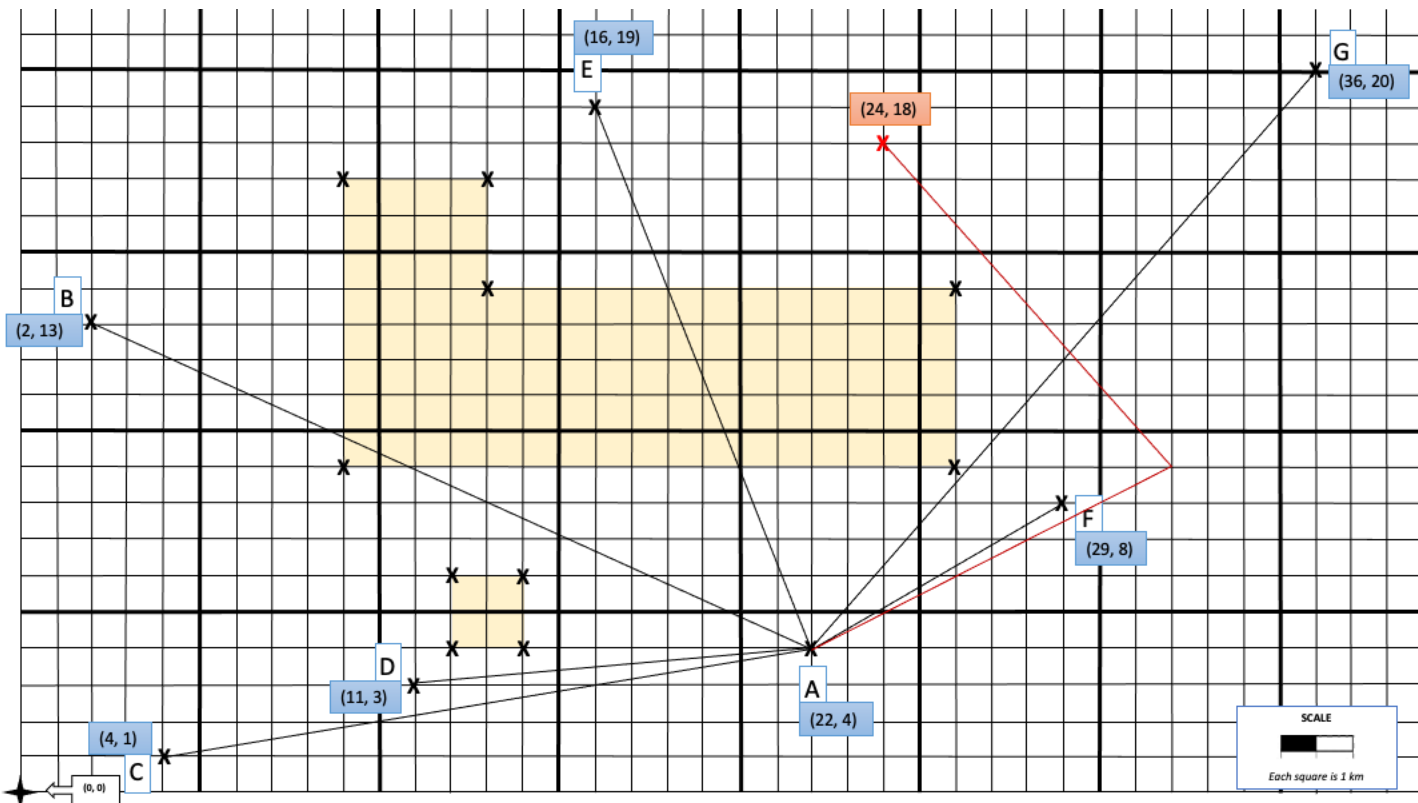
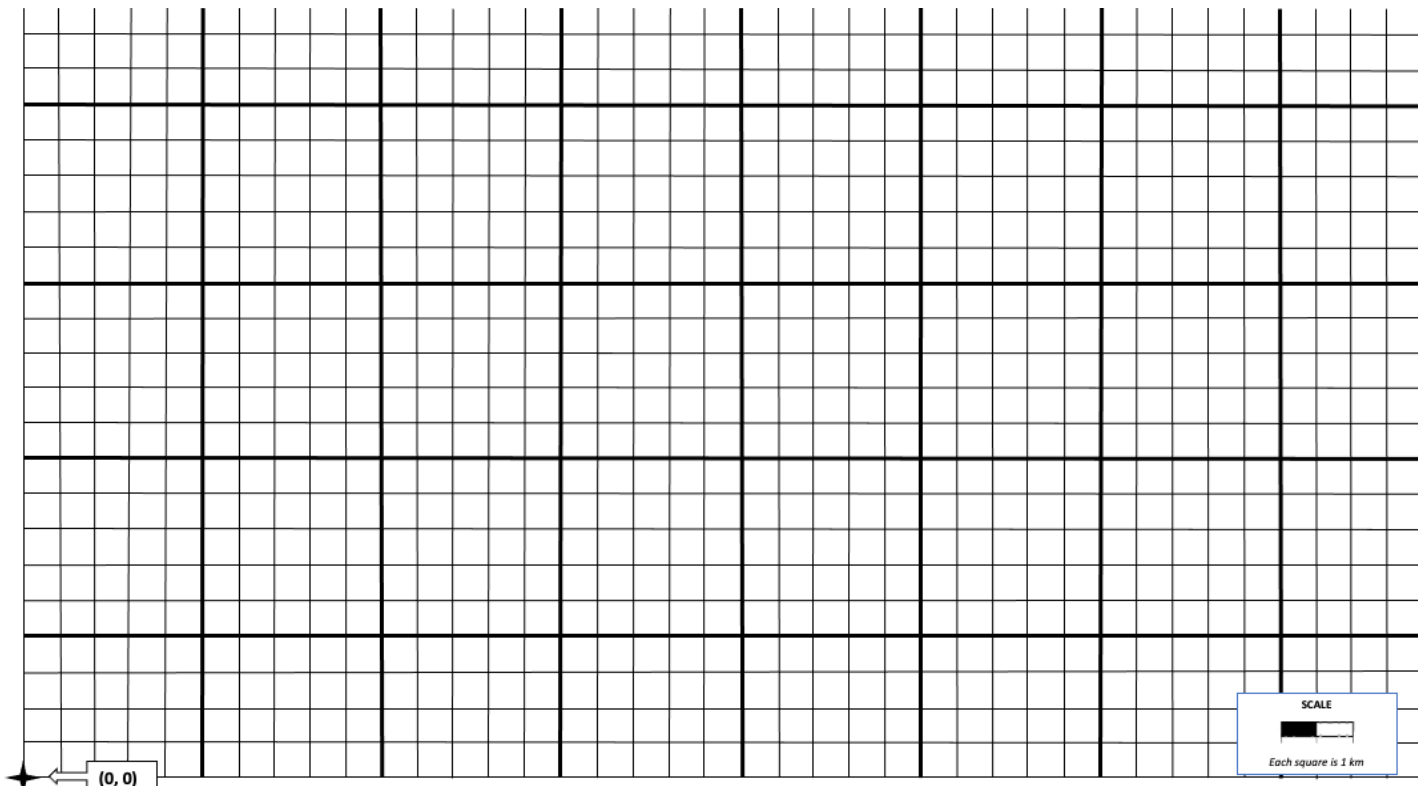
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From A to D: <u>It can fly straight</u>	From A to G: <u>It can fly straight</u>

3. The city is planning on building a new vertiport at the coordinates (24, 18). Because of the geofenced area around the airport, you cannot send an air taxi straight from your headquarters to this new vertiport.

So, you decide to create a waypoint where your air taxi can turn. The air taxi should be able to fly straight from headquarters to this point and then straight from this point to the new vertiport, all without entering a geofenced area. You need to find **one point** east (to the right) of the geofenced area that could act as the waypoint. Enter the coordinates of your point below, graph it, and show both legs on the air taxi's flightpath as evidence that the waypoint you chose met the criteria.

Coordinates of the waypoint: **There are many possible answers; the graph shows the point (19, 4) as one possible solution.**



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