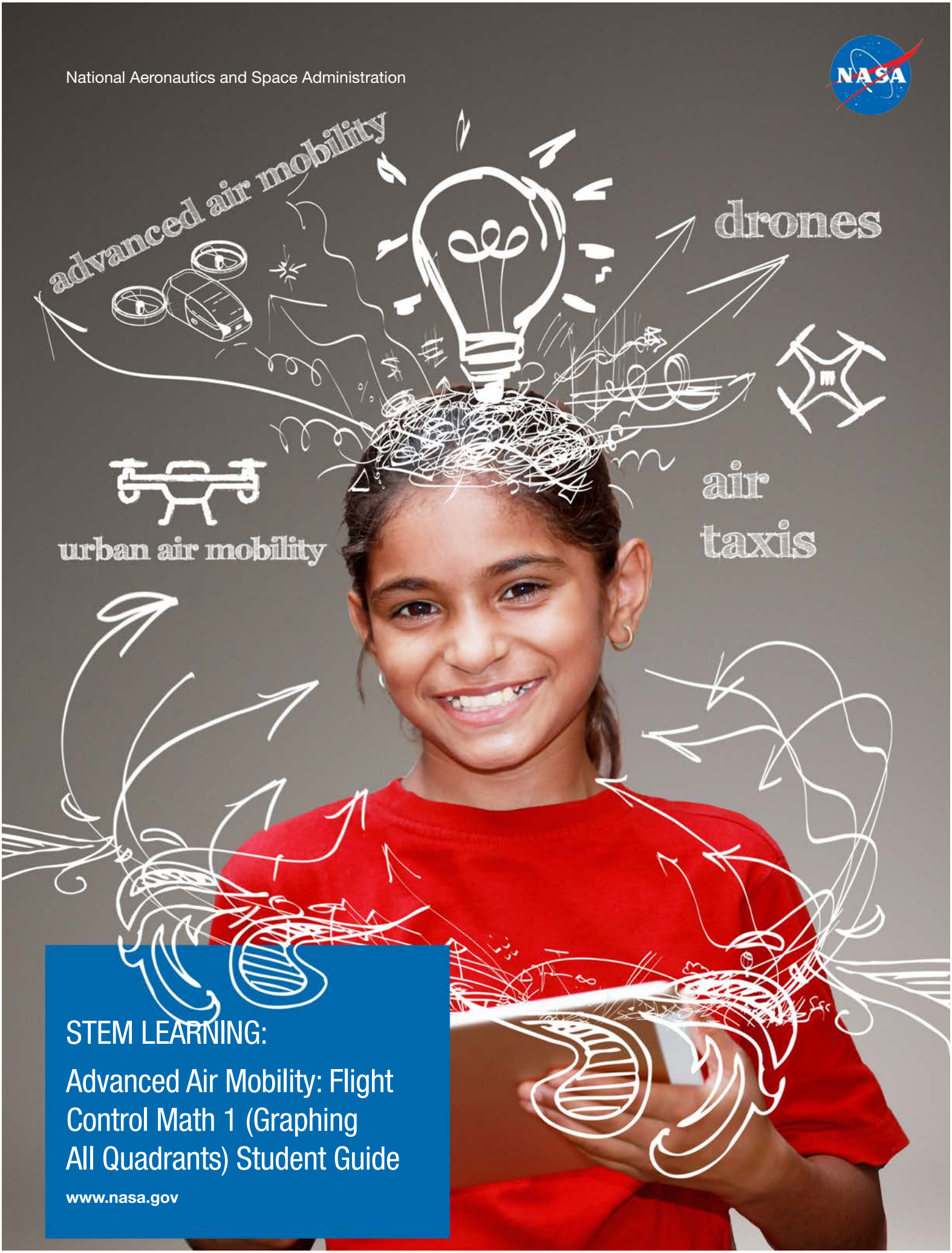
National Aeronautics and Space Administration



STEM LEARNING:

Advanced Air Mobility: Flight Control Math 1 (Graphing All Quadrants) Student Guide

www.nasa.gov

AIR TAXIS

NASA is leading the nation to quickly open a new era in air travel called Advanced Air Mobility, or AAM. The vision of AAM is that of a safe, automated, and affordable air transportation system for passengers and cargo in both urban and rural settings.

Air taxis are small, propeller driven aircraft capable of carrying passengers. Most of them are autonomous, meaning they do not have pilots onboard—a microcomputer installed on the air taxi controls flight. Since they operate above the roads, they can efficiently transport people because they can fly above traffic; consequently, this decreases traffic on roads.

Figure 1. Air taxis efficiently transport passengers from place to place. Credit: NASA

GEOFENCING

Figure 2. Geofencing creates virtual walls around areas. Credit: NASA

Because of where air taxis and other unmanned aircraft will be flying, there will be places they cannot fly. For example, the airspace over airports or military bases needs to be kept clear. Failure to do so could result in collisions, which puts many people at risk.

Geofencing, which was developed by NASA, is a system that creates virtual fences around areas. When an unmanned aircraft approaches a geofenced area, a microcomputer onboard takes control and steers the aircraft away from that area. The microcomputer can also land the vehicle if it is unable to steer it away.

USING MATH ON MAPS

Have you ever tried to explain to someone where a certain place is? If you have, chances are you did so by explaining where the place is compared to another place. For instance, you might tell someone your school is located across the street from a park they know. The location you used for comparison is known as a **reference point**.

You also use a reference point when graphing points on a coordinate plane. In this case, the reference point is the origin, the point at the coordinates (0, 0). If you graph a point at the coordinates (3, 5), you are saying to go three spaces to the right of the origin and five spaces up from the origin.

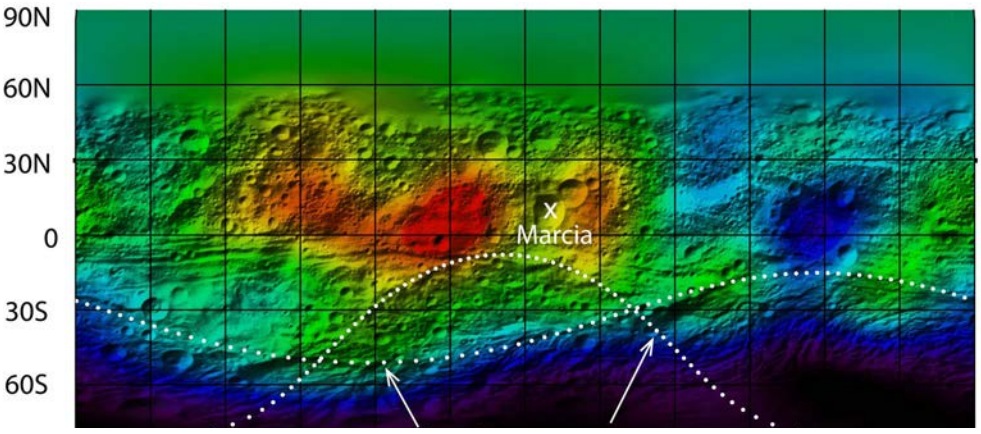


Figure 3. NASA created this map showing hydrogen on the asteroid Vespa and overlaid a grid to create reference points. Credit: NASA

We can use this graphing system when comparing points on a map. If a grid is drawn on a map and an origin is chosen, places on the map can be located using coordinates. With higher math skills, the distance between points can also be easily determined. In figure 4, you can see a satellite picture with the airport and state capitol marked. Then, in figure 5, you can see the same place changed into a map with a grid drawn on it.

In this activity you will be looking at Cheyenne, Wyoming. Cheyenne has two places that need geofencing. The first is Cheyenne Regional Airport and the second is the state capitol building. You will be using a map of Cheyenne with a grid over it to draw the geofenced areas. The origin is set to the location of the state capitol building.

Figure 4. Cheyenne, Wyoming has an airport and a state capitol building that have geofencing around them. Credit: USGS

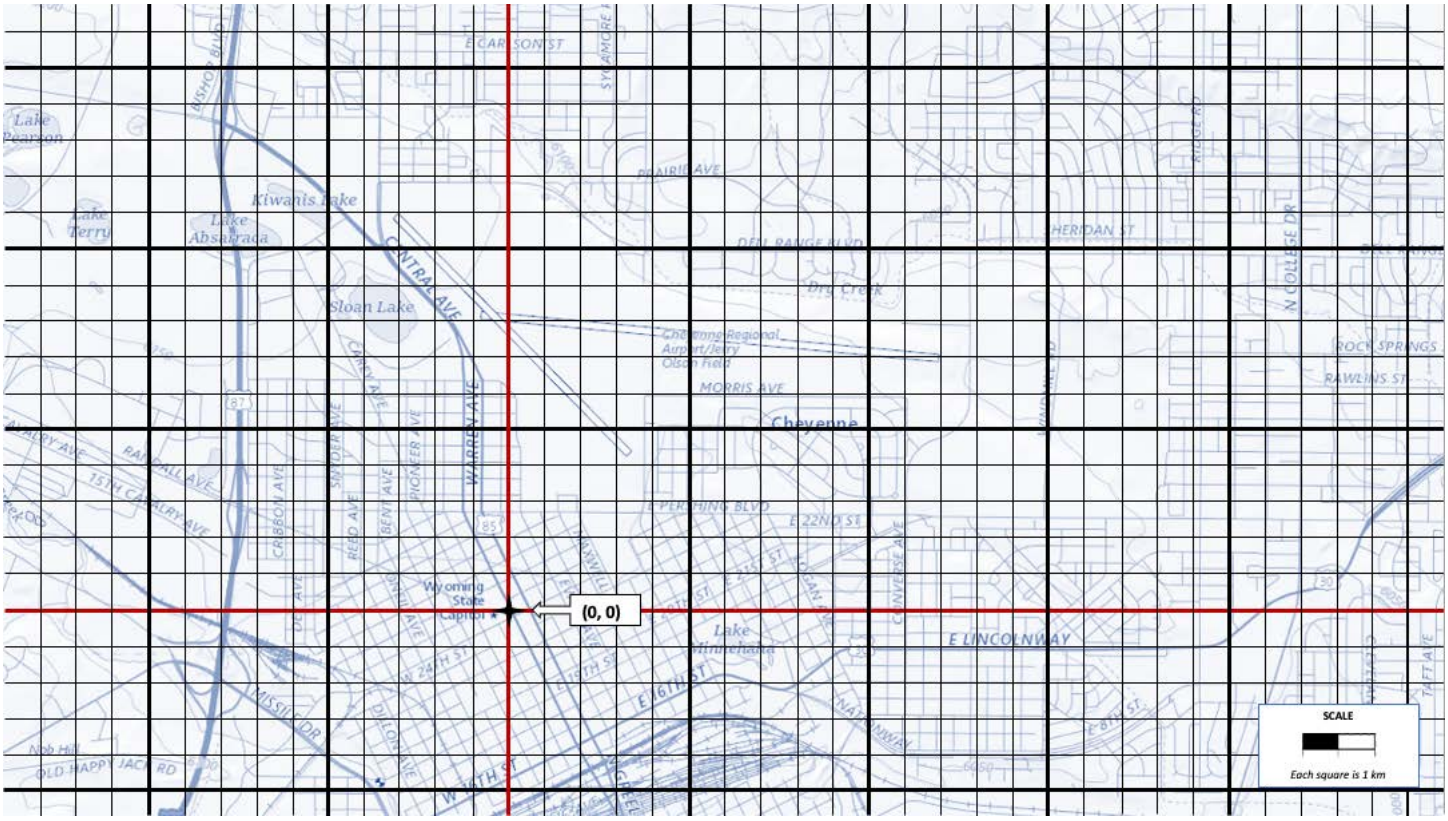


Figure 5. Putting a grid over a map allows you to use math to plot points and solve problems. Credit: USGS

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 coordinates 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.

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.

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 of 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: _____

   From A to C: _____

   From A to D: _____

   From A to E: _____

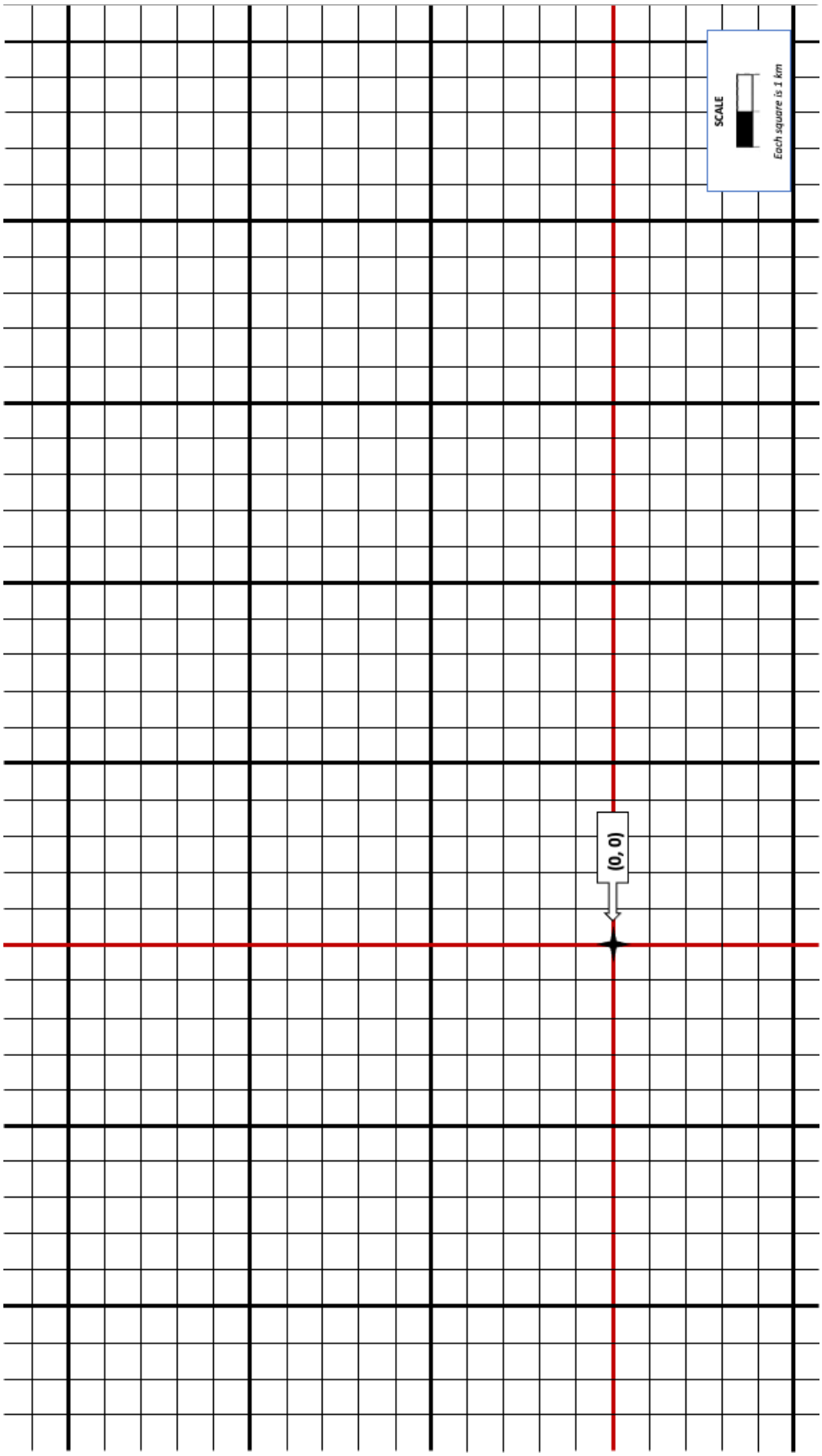
   From A to F: _____

   From A to G: _____

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: _____


SCALE
Each square is 1 km
(0, 0)

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EP-2020-04-505-HQ