Activity Four: 3, 2, 1… Lunch!

Educator Notes

Learning Objectives

Students will

- Use an x–y plane to plot coordinate pairs.
- Determine the distance between points on a coordinate plane by counting, using a ruler, or applying the Pythagorean Theorem or Distance Formula.
- Engage in computational thinking while exploring the challenges NASA engineers face when programming unmanned aircraft systems (UAS).

Challenge Overview

Students will engage in cooperative game play with other teams to simulate navigating a drone from a given start point to an end point with the shortest flight path while avoiding obstacles. The team who discovers the shortest distance will win the game.

Suggested Pacing

60 to 90 minutes

National STEM Standards

Mathematics (CCSS)	
Content Standards • CCSS.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. • CCSS.MATH.CONTENT.6.NS.C.6.B: Understand signs of numbers in ordered pairs as indicating locations in quadrants of the coordinate plane; recognize that when two ordered pairs differ only by signs, the locations of the points are related by reflections across one or both axes. • CCSS.MATH.CONTENT.6.NS.C.6.C: Find and position integers and other rational numbers on a horizontal or vertical number line diagram; find and position pairs of integers and other rational numbers on a coordinate plane.	*Content Standards (continued)* • CCSS.MATH.CONTENT.8.G.B.8: Apply the Pythagorean Theorem to find the distance between two points in a coordinate system. *Mathematical Practices* • MP.1: Make sense of problems and persevere in solving them. • MP.2: Reason abstractly and quantitatively. • MP.4: Model with mathematics. • MP.6: Attend to precision.

Challenge Preparation

- Read the introduction and background information, Educator Notes, Student Handout, Finding the Distance Worksheet, and game sheets to become familiar with the game. It is helpful to have a printed copy of the Student Handout and the game sheets, including the game board, while reading through the Educator Notes.
- Determine if students will play individually or in teams of two. A minimum of two teams is required to play a game, but there is no maximum. Assess prior knowledge before assigning teams.
- Use differentiation if needed to find the distance traveled on the game board. Students may count squares, measure distance with a metric ruler to the nearest tenth of a centimeter, or apply the Pythagorean Theorem or Distance Formula. Students may "level up" as they progress through the school year and learn new techniques for finding distance.
- Make copies of the Student Handout, Finding the Distance Worksheet, and game sheets.

Materials

- ☐ Student Handout
- ☐ Finding the Distance Worksheet
- ☐ Game sheets
  - Setting Up the Game Board, including game board, game pieces, table, and tracker
  - Printable Die, Spinner, Coins, and Rulers (as needed)
  - Encounters Extension Game
  - Time Variable Extension Game

- ☐ Graph paper (1/2 cm) or printed game board
- ☐ Scissors
- ☐ Tape
- ☐ Pencil
- ☐ 6-sided dice, printable dice, printable spinner, or use a virtual-dice-rolling website
- ☐ 2-sided coin, printable coin, or use a virtual coin flipping website
- ☐ Metric ruler (optional)
- ☐ Calculator (optional)
- ☐ Dry erase markers (optional if laminating game boards)

Safety

- Supervise students when using scissors to cut out shapes.

Introduce the Challenge

- Provide context for the challenge using the introduction and background information provided in the guide. Define unmanned aircraft systems (UAS) and discuss the work NASA is doing to make UAS flight safer. Ensure students understand the difference between UAS and unmanned aerial vehicles (UAVs) before moving forward. Both terms will be used throughout this activity.
- Introduce the concept of advanced air mobility (AAM) to students with the NASA video, "What Is AAM?" https://youtu.be/Vu1VWEvgd24
- Discuss the challenges of managing and navigating the National Airspace System (NAS) and discuss how UAS pilots might choose their flight paths. What safety concerns do engineers and pilots need to consider when flying UAVs through the national airspace?
- Inform students they will be playing a cooperative game with their peers.
- Before sharing the following scenario, explain that the goal of the game is to navigate a UAV from takeoff, to waypoints, to the destination, and back to the starting position, all while traveling the shortest distance on the board.
- Share the following scenario:

  Imagine your community in the future when autonomous flying vehicles routinely conduct land surveys, provide delivery services, and run your errands. You are sitting in class the period before lunch and realize that in your rush out the door this morning, you forgot your lunch and the science project you are supposed to turn in later today. You happen to have a personal UAV at home that can bring your project to the school. You also remember your local diner is serving your favorite meal today, so you can have your UAV stop to grab some lunch along the way. Unfortunately, your UAV has altitude limitations, so it must fly around certain obstacles (e.g., buildings, tall trees, and towers). Your mission is to safely navigate your aircraft from home, to the diner, to school, and back home again while avoiding these obstacles. You need to get the UAV there quickly or you might miss lunch.

- Discuss the criteria and constraints for the game.

Share With Students

Brain Booster

For more than 25 years, NASA has conducted air traffic management system research in partnership with the Federal Aviation Administration (FAA), providing a variety of computer-based tools that help improve flight efficiency, reduce delays, and reduce fuel use and emissions, all while maintaining safety in increasingly crowded skies.

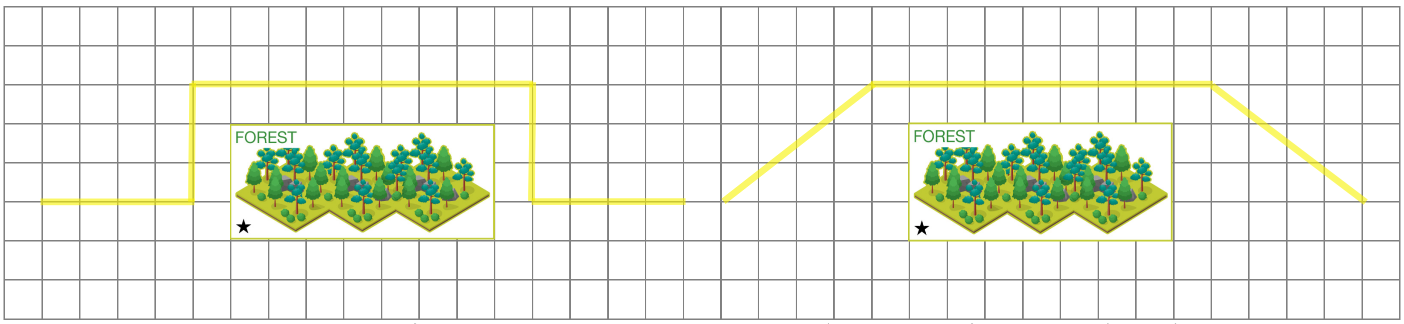
Learn more: https://www.nasa.gov/sites/default/files/atoms/files/utm-factsheet-09-06-16.pdf

On Location

NASA's Ames Research Center in California's Silicon Valley is creating a research platform that will help manage large numbers of drones flying at low altitude along with other airspace users. Known as UAS Traffic Management, or UTM, the platform's goal is to create a system that can integrate drones safely and efficiently into air traffic that is already flying in low-altitude airspace.

Learn more: https://www.nasa.gov/ames/utm/

Criteria	Constraints
1 to 2 players per team.	Game pieces cannot "hang off" the game board.
Minimum of 2 teams, no maximum number of teams.	Game pieces cannot overlap.
Each team will use their own game board.	The UAV cannot fly over or across game pieces (obstacles).
Opposing teams must have the same game board setup.	The path from home to school cannot be completely blocked by obstacles.
When visiting a game piece for a task, the UAV must land at the grid corner nearest the star.	For safety, the UAV cannot travel within the space 1 unit from game pieces (see examples) unless it is approaching the star for a task.
The UAV must turn at corners of the grid so that all x- and y-coordinates are whole numbers.	Once game setup is complete, teams cannot look at other teams' game boards until all game play is finished.

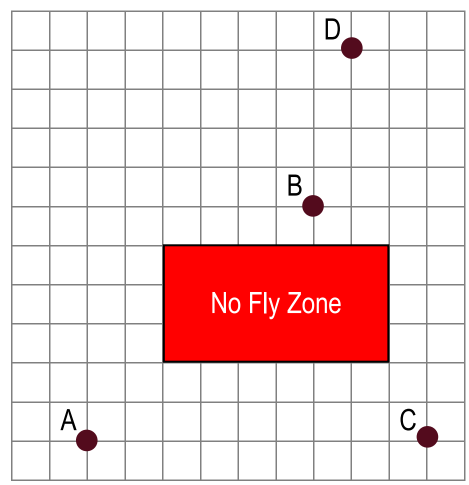


Examples showing UAV flight path turning at grid corners and staying at least 1-unit space away from game piece (obstacle).

Facilitate the Challenge

Meet the Problem

- Ask students to restate the problem in their own words.
- To help students visualize the challenge, plot four random points on a sample game board with an obstacle or "No Fly Zone" game piece. See example at right.
- Label the points (A, B, C, D). Ask students to brainstorm ways they can avoid the obstacle when moving between two points (e.g., A to B). How do they determine the safest and shortest route?
- Ask students to discuss which path would be the shortest if they had to connect all four points in any order while avoiding the obstacle, or game piece.
- If needed, review with students the selected method for finding distance before playing the game.



Explore Knowns and Unknowns

- Answer any questions students may have to ensure all teams understand the following:
  - The materials needed for the game
  - The rules of the game (criteria and constraints)
  - The method for finding distance (use the Finding the Distance worksheet to see examples for counting, measuring with a ruler, and applying the Pythagorean Theorem and Distance Formula)
  - The steps for setting up the game board (use the Setting Up the Game Board sheet to help teams position game pieces in preparation for game play)
- Be prepared to provide additional examples or run a mock game, including game board setup, filling in the Game Tracker, and finding distance.

Generate Possible Solutions

- Before starting the game, make sure
  - All teams are ready.
  - Game board is set up (one per team; identical game boards for opposing teams).
- Remind students of the objective of the game and rules of play.
  - **Objective**: Each team must find the shortest path to fly the UAV from home, to the diner, to school, and back home again.
  - The winner is the team with the shortest distance at the end of the game.
  - The UAV can move horizontally, vertically, and diagonally (unless using the counting method) on the game board.
  - During the game, each team will record data in their Game Tracker.
  - The UAV must stay at least one unit away from obstacles.
  - When visiting a game piece, the UAV must land on the corner nearest the star.
  - The UAV cannot fly over obstacles.
  - Teams must document work, including any calculations, data in the Game Tracker table, and flight path on the game board.
- Let the games begin!

Consider Consequences

- In this step, teams will have thought through possible solutions and must now do the calculations to determine the distances of each potential route.
- Using the data in the Game Tracker table, teams will calculate the distance for each turn or line segment and then find total distance traveled.
- Each team must share their documentation with an opposing team at the end of game play to cross-check work. Mistakes must be corrected before determining a winner. The educator may need to intervene if there are any discrepancies.
- All opposing teams will compare their total distances traveled. The team with shortest total path wins the game.

Present Findings

- Engage students with the following discussion questions:
  - What was the biggest challenge you faced while navigating your UAV?
  - If you could replay the game, what moves would you make differently?
  - How did your calculated distances impact the decisions you made during the game?
  - Based on what you learned from playing, what might you create to make UAS flight safer if you were a NASA engineer?
  - Given the scenario, brainstorm ways NASA engineers solve similar problems in the NAS. How could NASA engineers ensure that UAVs stay away from obstacles?
  - Think about your own community. What obstacles would your UAV face when flying between your home and your school?

Extensions

After students have mastered the basic game, they can challenge themselves with one or more extensions and variations.

- Encounters Extension Game: Encounters are random events that might impact a planned flight path (e.g., new obstacles, unexpected detours, or penalties). During the Encounters Extension Game, teams will need to rethink their plan after each turn as these encounters will work for or against their strategy. Encounters will be determined by the roll of a die.
- Time Variable Extension Game: This game challenges students to use the formula for speed and distance to determine the amount of time it takes for a UAV to travel between locations. Random “speed zones” will vary the amount of time it takes to navigate different areas of the game board. Teams must strategize the pros and cons in planning the fastest possible route.
- Additional extensions and variations:

- Ask students to create their own scenario for the game.
- Ask students to create their own game boards of different sizes for an added challenge.
- Add a constraint to solve the task using the fewest turns.
- Require teams to find the shortest distance while stopping at each game piece.
- Play the game as a class on a life-size grid with a student representing the UAV. Include objects to avoid on the grid. The class will work together to determine the shortest path and calculate or measure the distance.
- Play the game as a large group. Split the whole group into two teams. This method requires greater educator involvement but may help students understand the rules before playing independently.
- Using a block-based programming language (e.g., Scratch or Snap!), have students create a virtual game board to play the game.

Activity Four: 3, 2, 1… Lunch!

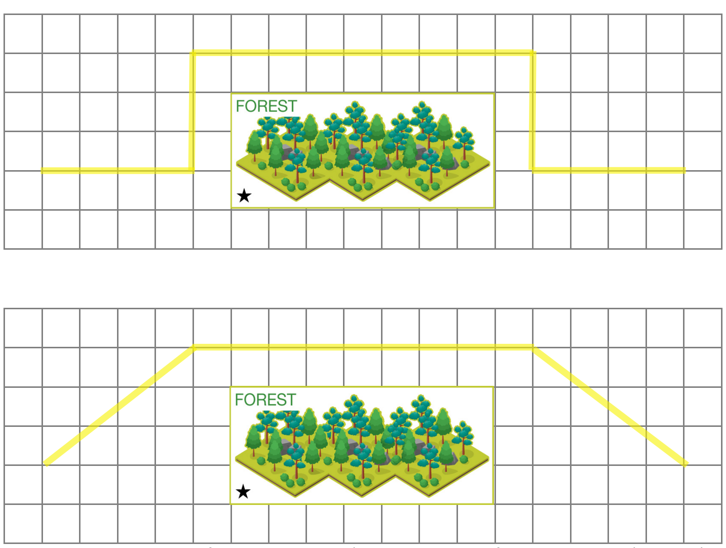
Student Handout

Your Challenge

You will engage in cooperative game play with other teams to simulate navigating a drone from a given start point to an end point with the shortest flight path while avoiding obstacles. The team who discovers the shortest distance will win the game.

Scenario: Imagine your community in the future when autonomous flying vehicles routinely conduct land surveys, provide delivery services, and run your errands. You are sitting in class the period before lunch and realize that in your rush out the door this morning, you forgot your lunch and the science project you are supposed to turn in later today. You happen to have a personal unmanned aerial vehicle (UAV) at home that can bring your project to the school. You also remember your local diner is serving your favorite meal today, so you can have your UAV stop to grab some lunch along the way. Unfortunately, your UAV has altitude limitations, so it must fly around certain obstacles (e.g., buildings, tall trees, and towers). Your mission is to safely navigate your aircraft from home, to the diner, to school, and back home again while avoiding these obstacles. You need to get the UAV there quickly or you might miss lunch.

Criteria	Constraints
1 to 2 players per team.	Game pieces cannot "hang off" the game board.
Minimum of 2 teams, no maximum number of teams.	Game pieces cannot overlap.
Each team will use their own game board.	The UAV cannot fly over or across game pieces (obstacles).
Opposing teams must have the same game board setup.	The path from home to school cannot be completely blocked by obstacles.
When visiting a game piece for a task, the UAV must land at the grid corner nearest the star.	For safety, the UAV cannot travel within the space 1 unit from game pieces (see examples), unless it is approaching the star for a task.
The UAV must turn at corners of the grid so that all x- and y-coordinates are whole numbers.	Once game setup is complete, teams cannot look at other teams' game boards until all game play is finished.



Examples showing UAV flight path at least 1-unit space away from game piece (obstacle).

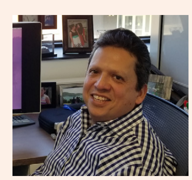
Fun Fact

Researchers at NASA's Langley Research Center in Hampton, Virginia, have developed an assured safety net technology for unmanned aircraft systems called "Safeguard." Safeguard should alleviate the dangers of unmanned aircraft flying beyond their authorized perimeters and into no-fly zones. The system does this with the use of geofencing like an invisible dog fence.

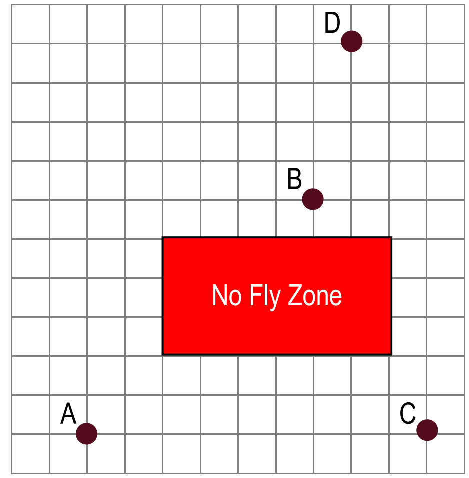
Learn more: https://www.nasa.gov/langley/business/feature/nasa-langley-s-safeguard-system-for-uavs-aims-to-take-flight

Career Corner

César A. Muñoz works on the development of formal methods technologies for NASA's Next Generation of Air Traffic Systems, Validation and Verification of Flight Critical Systems, Unmanned Aircraft Systems Integration in the National Airspace System, and Safe Autonomous Systems Operations projects.



Learn more: https://shemesh.larc.nasa.gov/people/cam/



Meet the Problem

- What is the problem you are trying to solve in this scenario?
- What questions do you have about this problem?
- Brainstorm ways to move from point A to point B without touching the “No Fly Zone” area. What is the shortest route from A to B?
- What is the shortest path that would connect all four points (in any order) while avoiding the “No Fly Zone” area?
- Your teacher will assign you to a team, determine your opposing team(s), and identify which method your team will use to find distance between two points on the graph.
  - Counting
  - Measuring with a metric ruler
  - Pythagorean Theorem
  - Distance Formula

Explore Knowns and Unknowns

- As a team, review each of the following:
  - The materials needed for the game
  - The rules of the game (criteria and constraints)
  - The method for finding distance (assigned by your teacher)
  - The steps for setting up the game board (see the Setting Up the Game Board worksheet to prepare for game play)
- What questions do you have for your teacher?
- Work with the opposing team(s) to set up the game board.

Safety

- Remember to be careful and stay seated when using scissors.

Generate Possible Solutions

- Before starting the game, check that your team’s game board is identical to that of your opposing team(s), including placement and orientation of all game pieces.
- Remember the objective of the game and rules of play.
  - **Objective**: You must find the shortest path to fly your UAV from home, to the diner, to school, and back home again.
  - The winner is the team with the shortest distance at the end of the game.
  - The UAV can move horizontally, vertically, and diagonally (unless using the counting method) on the game board.
  - During the game, each team will record data in their Game Tracker.
  - The UAV must stay at least one unit away from obstacles.
  - When visiting a game piece, the UAV must land on the corner nearest the star.
  - The UAV cannot fly over obstacles.
  - Teams must document their work, including any calculations, data in the Game Tracker table, and flight path on the game board.
- Let the games begin!

?!? Consider Consequences

- In this step, you will have thought through possible solutions and must now do the calculations to determine the distances of each potential route.
- Using the data in the Game Tracker table, find the distance for each turn or line segment and then find the total distance traveled.
- After finishing the game, share your work with an opposing team to cross-check your work. This includes the Game Tracker table, any calculations, and the flight path on the game board. Mistakes must be corrected before determining a winner. Your teacher may need to intervene if there are any discrepancies.
- Compare your final total distance traveled with the opposing team(s). The team with the shortest total path wins the game.

Present Findings

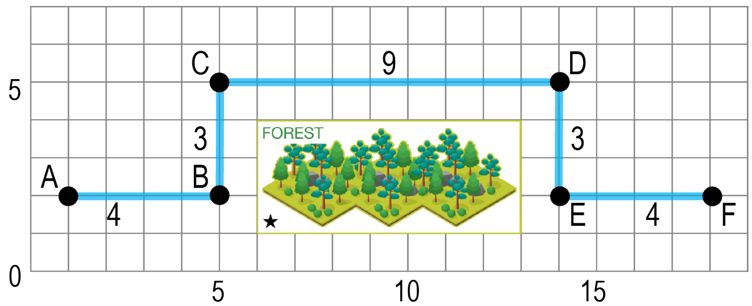
- Discuss the following questions within your team and with the whole group:
  - What was the biggest challenge you faced while navigating your UAV?
  - If you could replay the game, what moves would you make differently?
  - How did your calculated distances impact the decisions you made during the game?
  - Based on what you learned from playing, what might you create to make UAS flight safer if you were a NASA engineer?
  - Given the scenario, brainstorm ways NASA engineers solve similar problems in the NAS. How do engineers ensure that UAVs stay away from obstacles?
  - Think about your own community. What obstacles would your UAV face when flying between your home and your school?

Finding the Distance

As teams strategize the shortest distance to navigate the game board, they will record the start and end positions and the length of **each** line segment on the Game Tracker and then calculate the sum to determine the total distance traveled. The following are examples of the different methods for finding the length of a line segment.

Counting

To simplify the mathematics in this method, assume the UAV does not have the latest software upgrade and can only move horizontally or vertically on the game board (though it can make as many turns as needed). Count the units in each line segment and record the data in the Distance column.

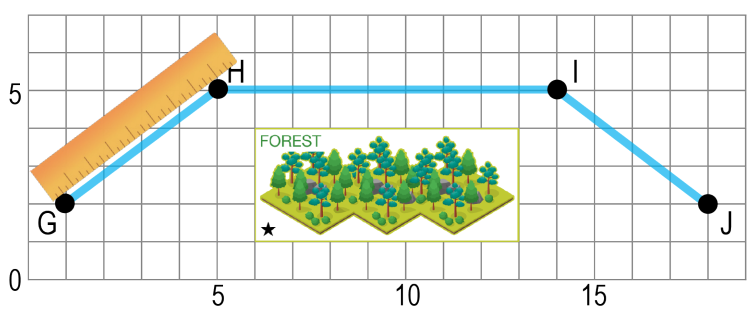


Game Tracker

Line segment	Start position, (x, y)	End position, (x, y)	Distance, units
AB	(1,2)	(5,2)	4
BC	(5,2)	(5,5)	3
CD	(5,5)	(14,5)	9
DE	(14,5)	(14,2)	3
EF	(14,2)	(18,2)	4
		Total distance	23

Using a Ruler

Measure the line segments in centimeters to the nearest tenth and record data in the Distance column.



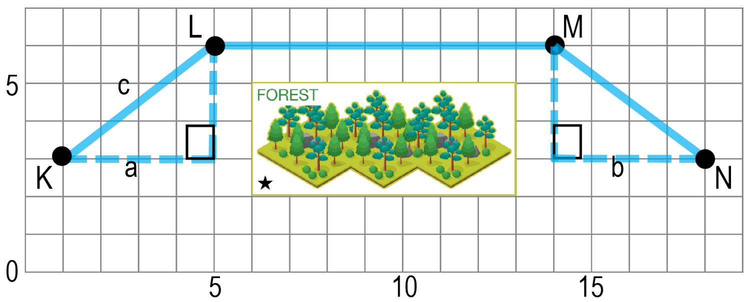
Game Tracker

Line segment	Start position, (x, y)	End position, (x, y)	Distance, cm*
GH	(1,2)	(5,5)	2.5
HI	(5,5)	(14,5)	4.5
IJ	(14,5)	(18,2)	2.5
		Total distance	9.5

*Note: The distance measured with the ruler can be compared to the other three methods for finding distance by using the scale of 1 unit = 0.5 cm, so 9.5 cm is equivalent to 19 units.

Pythagorean Theorem

The length of horizontal or vertical line segments can be calculated by subtracting the corresponding x or y coordinates. Pythagorean Theorem may be applied to find the length of any diagonal line segments. It may be helpful to sketch a right triangle on the grid to visualize the perpendicular legs of the triangle which are used to calculate the hypotenuse (or the side opposite the right angle). Apply the Pythagorean Theorem showing all work and round to the nearest tenth. Record data in the Distance column.



Game Tracker

Line segment	Start position, (x, y)	End position, (x, y)	Distance, units
KL	(1,3)	(5,6)	5
LM	(5,6)	(14,6)	9
MN	(14,6)	(18,3)	5
		Total distance	19

Pythagorean Theorem: $\mathbf{a^2 + b^2 = c^2}$

$4^2 + 3^2 = \mathbf{c^2}$

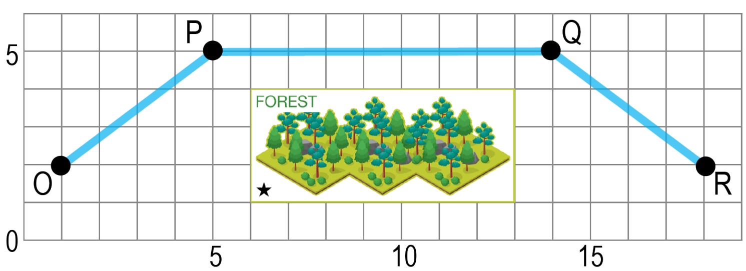
$16 + 9 = \mathbf{c^2}$

$25 = \mathbf{c^2}$

$5 = \mathbf{c}$

Distance Formula

For each line segment, use the Distance Formula to find the length of the line segment. Show all work and round to the nearest tenth. Record data in the Distance column.



Game Tracker

Line segment	Start position, (x, y)	End position, (x, y)	Distance, units
OP	(1,2)	(5,5)	5
PQ	(5,5)	(14,5)	9
QR	(14,5)	(18,2)	5
		Total distance	19

Distance Formula: $\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$

$$\begin{aligned}\text{Distance OP} &= \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}\\ &= \sqrt{(5-1)^2 + (5-2)^2}\\ &= \sqrt{(4)^2 + (3)^2}\\ &= \sqrt{16+9}\\ &= \sqrt{25}\\ &= 5\end{aligned}$$

$$\begin{aligned}\text{Distance QR} &= \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}\\ &= \sqrt{(14-5)^2 + (5-5)^2}\\ &= \sqrt{(9)^2 + (0)^2}\\ &= \sqrt{81+0}\\ &= \sqrt{81}\\ &= 9\end{aligned}$$

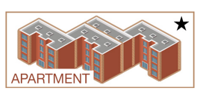
Setting Up the Game Board

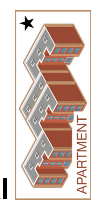
- For each game piece, the x-coordinate is provided and the y-coordinate for Home and School are also given. To find the y-coordinate for the remaining game pieces, roll two 6-sided dice (or one die twice), multiply the two values together, and record that number in the y-coordinate column of the Game Board Setup Table. Repeat this process for all game pieces. Teams may take turns rolling for each game piece.

Game Board Setup Table

Game pieces	x-coordinate	y-coordinate	Direction
Home	0	0	--
Apartment building	1		
Hospital	6		
Diner (stop for lunch)	11		
Forested area	17		
Shopping center	24		
Cell tower	27		
School	30	36	--

- To determine if the game piece will be placed in a vertical or horizontal orientation, flip a coin. If the coin lands on heads, the game piece is placed in the horizontal position. If the coin lands on tails, then the game piece is placed in the vertical position. Record this information in the Direction column of the Game Board Setup Table. Teams may take turns flipping the coin for each game piece. For square pieces, the only difference will be the location of the star.

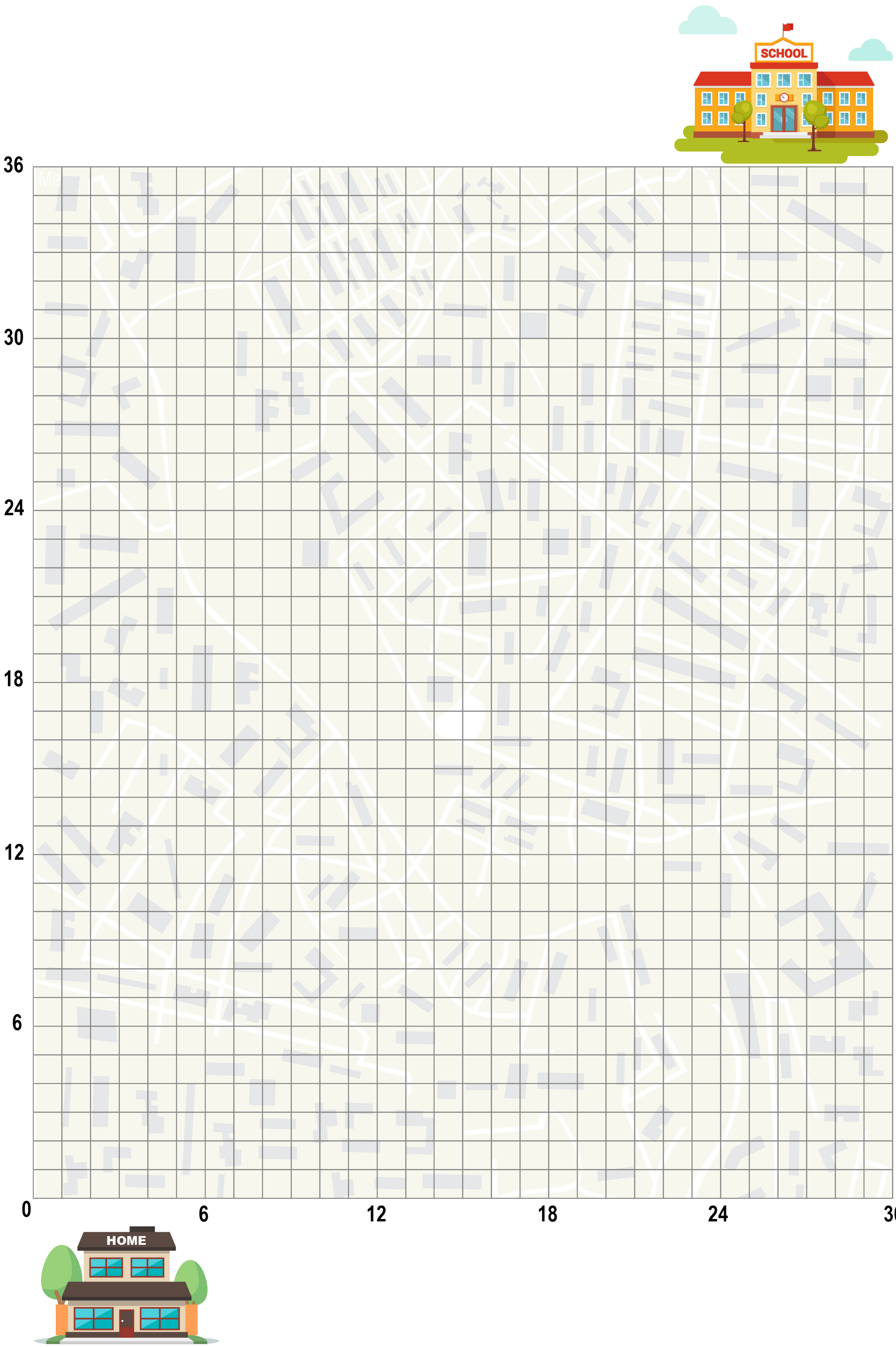
Heads = horizontal 

Tails = vertical 

- After completing the Game Board Setup Table, opposing teams will work together to ensure their game boards are identical. Teams must place each game piece into the correct position (x- and y-coordinates) and orientation (horizontal or vertical) according to the table. Teams must decide together which corner of the game piece will align with the associated coordinate pair.
- Refer to the criteria and constraints if needed while setting up the board. Repeat until all obstacles are on the board.

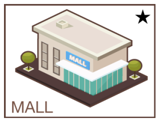
Criteria	Constraints
1 to 2 players per team.	Game pieces cannot “hang off” the game board.
Minimum of 2 teams, no maximum number of teams.	Game pieces cannot overlap.
Each team will use their own game board.	The UAV cannot fly over or across game pieces (obstacles).
Opposing teams must have the same game board setup.	The path from home to school cannot be completely blocked by obstacles.
When visiting a game piece for a task, the UAV must land at the grid corner nearest the star.	For safety, the UAV cannot travel within the space 1 unit from game pieces unless it is approaching the star for a task.
The UAV must turn at corners of the grid so that all x- and y-coordinates are whole numbers.	Once game setup is complete, teams cannot look at other teams’ game boards until all game play is finished.

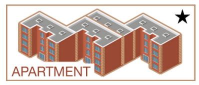
Game Board

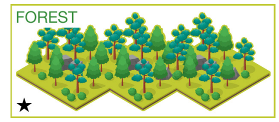


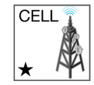
Game Pieces

Cut out the game pieces (obstacles) below to set up the game board.









Safety

- Be careful and stay seated when using scissors.

Game Tracker

Line segment	Start position, (x, y)	End position, (x, y)	Distance, units or cm
1	(0,0)		
2			
3			
4			
...			
		Total distance	

If needed, use your own paper to create a Game Tracker with more rows.

Encounters Extension Game

Encounters are random events that might impact a planned flight path (e.g., new obstacles, unexpected detours, or penalties). During the Encounters Extension Game, teams will need to rethink their plan after each turn as these encounters will work for or against their strategy. Encounters will be determined by the roll of a die. The overall objective remains the same. Each team must find the shortest path to fly the UAV from home, to the diner, to school, and back home again with additional challenges from the encounters during each turn of game play.

- Use the Game Board Setup Table to set up the game board just as you would in the basic game (see instructions on Setting Up the Game Board sheet).

Game Board Setup Table

Game pieces	x coordinate	y coordinate	Direction
Home	0	0	--
Apartment building	1		
Hospital	6		
Diner (stop for lunch)	11		
Forested area	17		
Shopping center	24		
Cell tower	27		
School	30	36	--

- Each team will independently strategize to find the shortest path to solve the basic game challenge and lightly sketch it on their game board with a pencil. Teams will then come back together, keeping their strategy hidden from the other team(s).
- Next, fill in the Encounters Table. Each team will choose three encounters from the Encounter Ideas list to add to the Encounters Table. If more than two teams are competing, the teacher will determine how the Encounters Table is set up.

Encounters Table

Number on die	Instructions for how the encounter will impact your turn
1	
2	
3	
4	
5	
6	

- **Encounter Ideas**
  - Game penalty: Subtract 3 from your total score at the end of the game.
  - Team advantage: Add 2 to an opponent's total score at the end of the game.
  - Team delay: Have an opponent of your choice stop at their nearest game piece to pick up a package on their next turn.
  - Running out of battery: Your UAV must return home to recharge (go directly home without stopping).

- Unexpected detour: Immediately move 2 spaces to the right or left of your current position.
- Unexpected stop: On your next turn, stop at the nearest game piece to pick up your friend's birthday present.
- Dropped an item: Immediately return to your last position to retrieve a lost item.
- Restricted airspace: The shortest path to your next destination has been temporarily restricted. Select a new route and try again.
- Unexpected obstacle: An aircraft flew across your flight path, forcing your UAV to stop early. Shorten your last line segment by one unit and indicate the new end position.
- Create your own encounter and define the impact.

- During the game, teams will take turns recording start position, end position, and encounter impact in the Encounters Game Tracker. Distances will be determined at the completion of the game.
- A turn will consist of a team moving their UAV one full line segment, rolling a 6-sided die to determine an Encounter impact, and implementing the Encounter. If an Encounter changes the UAV's position, record the new coordinates and re-strategize to find the shortest path from that point.
- Teams will alternate turns until all teams finish the game. Some teams may require more turns than others.

Encounters Game Tracker

Line segment	Start position, (x, y)	End position, (x, y)	Distance, units or cm	Encounter impact
1	(0,0)			
2				
3				
...				
		Total distance		

If needed, use your own paper to create a Game Tracker with more rows.

Time Variable Extension Game

The Time Variable Extension Game challenges students to use the formula for speed and distance to determine the amount of time it takes for a UAV to travel between locations. Random "speed zones" will vary the amount of time it takes to navigate different areas of the game board. Teams must strategize the pros and cons in planning the fastest possible route.

- Use the Time Variable Game Board Setup Table to set up the game board, using the same method for finding the y-coordinate (rolling dice) and direction (flipping coin) for each game piece (refer to Setting Up the Game Board sheet for details).

Time Variable Game Board Setup Table

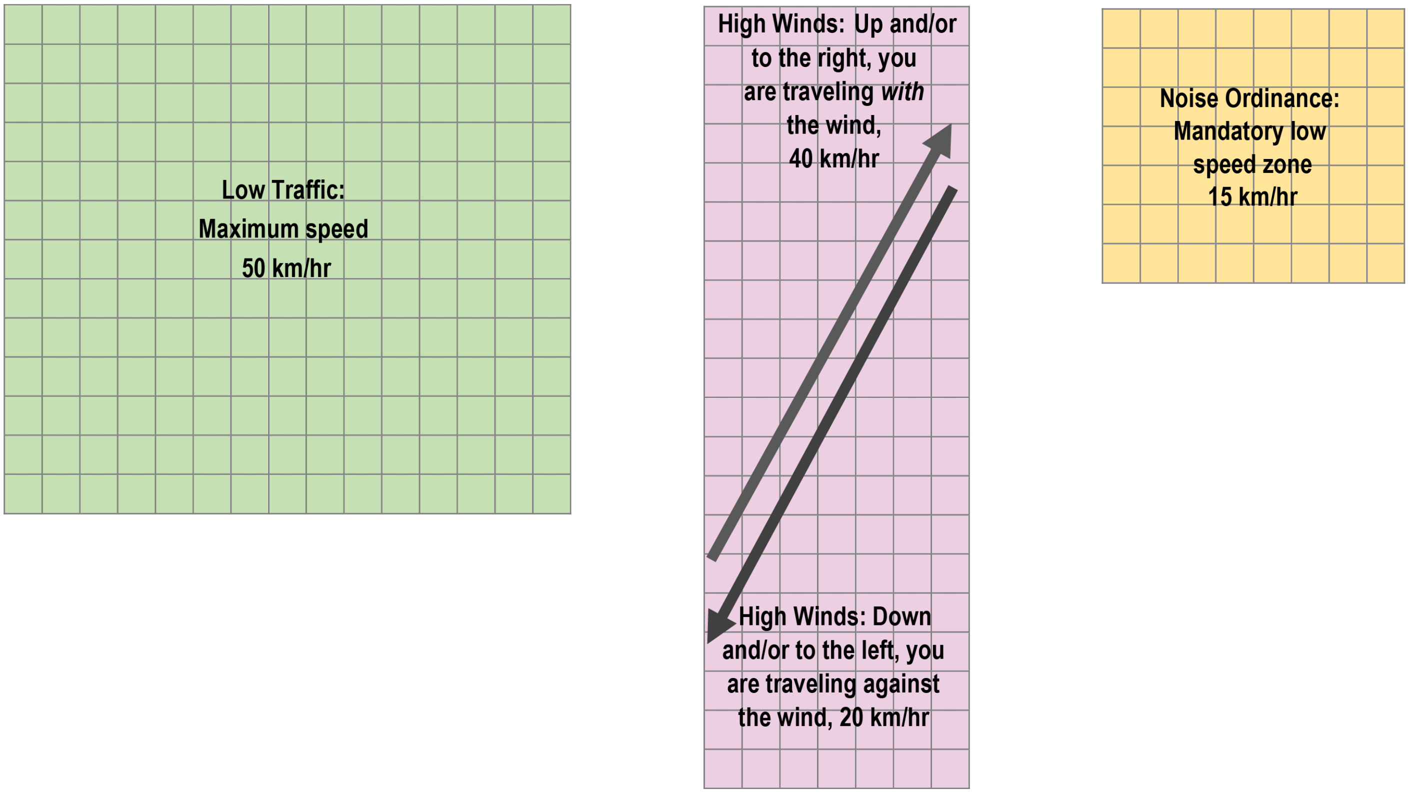
Game Piece	x coordinate	y coordinate	Direction
Home	0	0	--
Noise ordinance	0		
High winds	8		--
Low traffic	15		
Apartment building	1		
Hospital	6		
Diner (stop for lunch)	11		
Forested area	17		
Shopping center	24		
Cell tower	27		--
School	30	36	--

- The Speed Zone game pieces will be placed on the board first. Other game pieces (obstacles) may overlap the Speed Zones.
  - Outside of the Speed Zones, the UAV travels approximately 30 km/hr.
  - Noise Ordinance Speed Zone: Mandatory low speed, UAV speed cannot exceed 15 km/hr.
  - Low Traffic Speed Zone: No speed limit, maximize your speed at 50 km/hr.
  - High Wind Speed Zone: Speed drops by 10 km/hr heading into the wind and increases by 10 km/hr traveling with the wind.
- Teams will use the same methods as the basic game for finding the length of each line segment (counting, measuring with a ruler, or applying the Pythagorean Theorem or Distance Formula). The UAV may travel across Speed Zones, but teams must account for the change in speed when calculating travel time.
- Before selecting a path, teams should strategize which path would result in the **shortest time** to complete the task. Some speed zones will increase the UAV speed, which decreases the travel time, while other speed zones will slow it down and result in a longer travel time.
- Find the time by dividing distance by a constant speed. Round answers to the nearest hundredth. Time in hours can also be converted to minutes by multiplying by the unit conversion 60 minutes/1 hour.

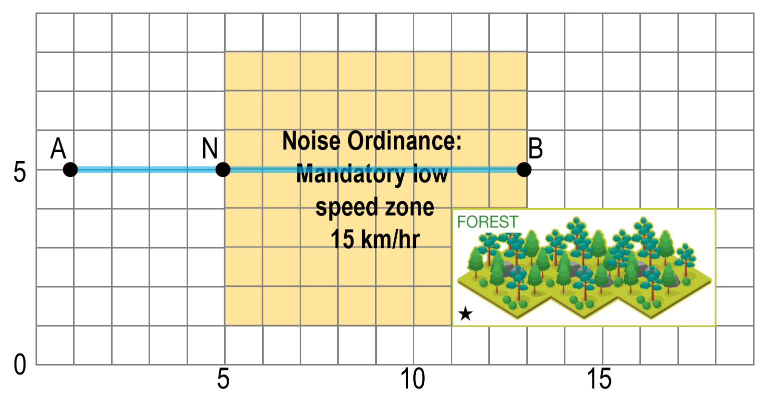
  $time = \frac{distance}{speed}$ where time is measured in hours, distance in kilometers, and speed in kilometers/hour.
- Each unit of length on the game board (0.5 cm grid) represents 1 km. Teams must use this scale factor to convert the distance determined by the length of the line segment into kilometers. (1 unit or 0.5 cm = 1 km)

Time Variable Game Pieces

Cut out the Time Variable Game pieces (speed zones) below to set up the Time Variable Game board.



- In the following example, the UAV would fly directly from point A to B, but the speed would change as it enters the Noise Ordinance Speed Zone. As a result, the team must first find the distance from A to N, where the speed is 30 km/hr, to find that travel time. Next, the team must find the distance from N to B, where the speed is 15 km/hr, to find that travel time. The total travel time from A to B would be the sum of the two times.



Example Game Tracker

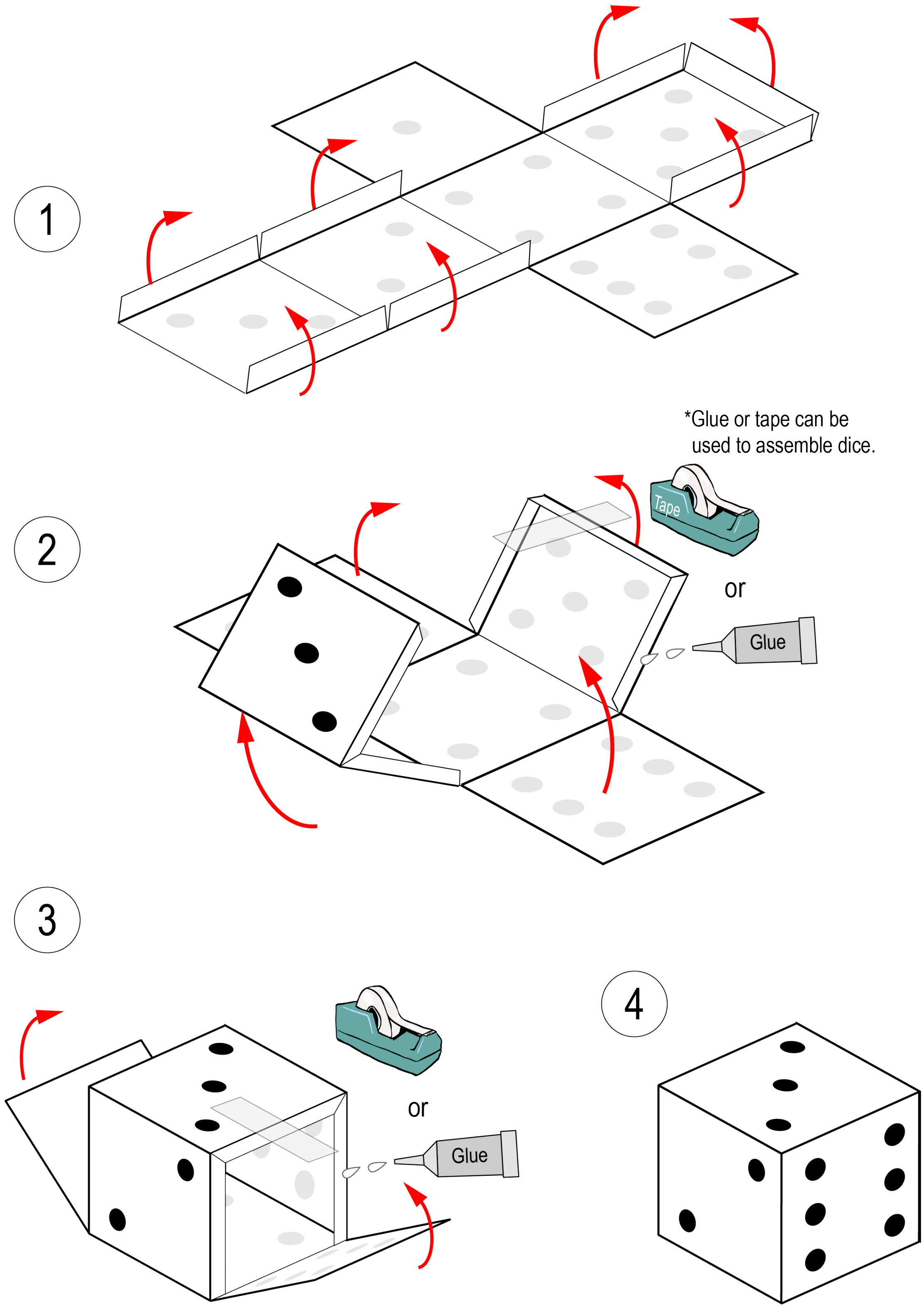
Line segment	Start position, (x, y)	End position, (x, y)	Distance, units or cm	Distance, km	Speed, km/hr	Time, hr	Time, min
AN	(1,5)	(5,5)	4 units	4	30	0.13	8
NB	(5,5)	(13,5)	8 units	8	15	0.53	32
					Total time	0.66	40

Time Variable Game Tracker

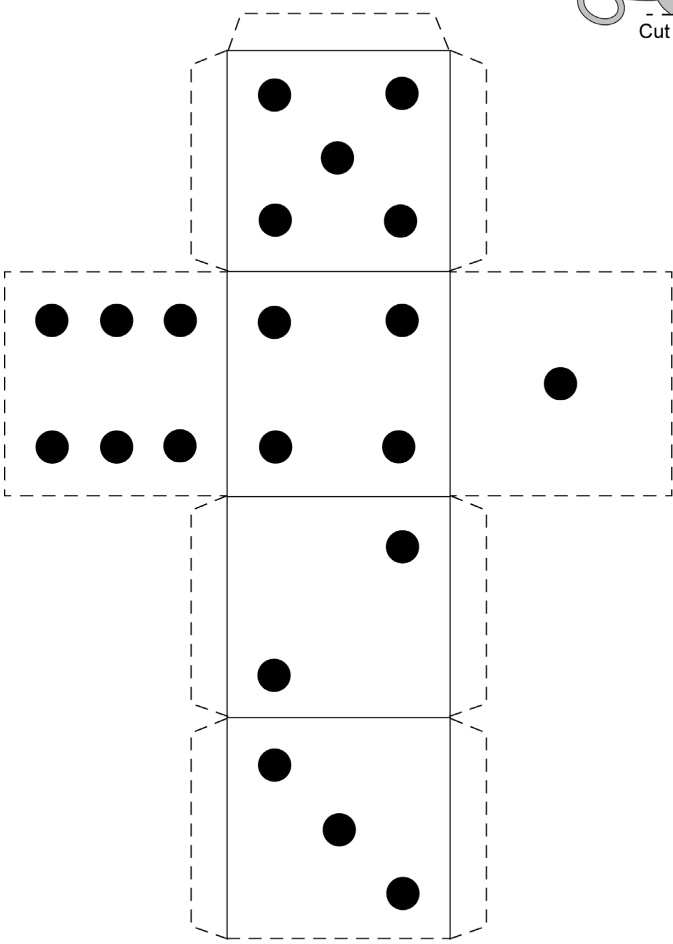
Line segment	Start position, (x, y)	End position, (x, y)	Distance, units or cm	Distance, km	Speed, km/hr	Time, hr	Time, min
	0,0						
...							
					Total time		

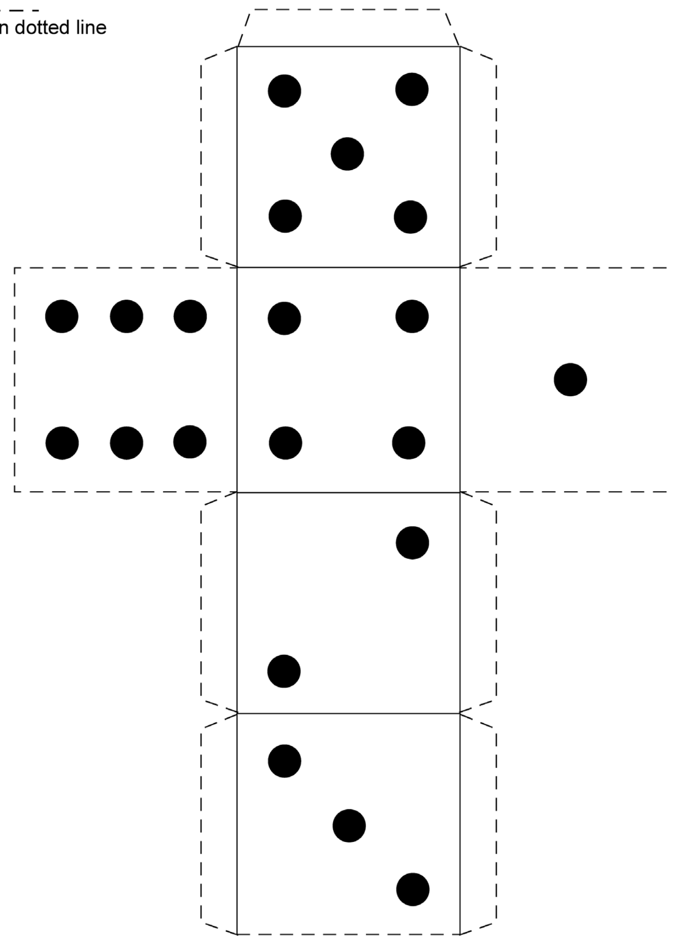
If needed, use your own paper to create a Game Tracker with more rows.

Printable Die Assembly Instructions



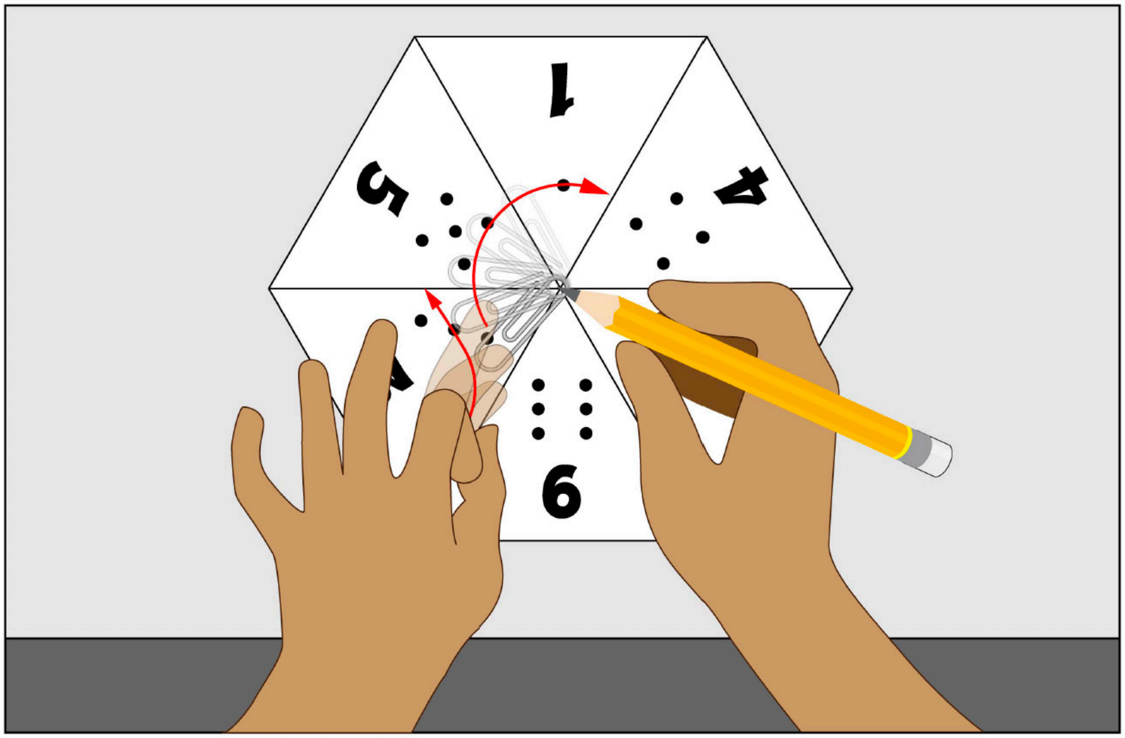
Cut out on dotted line



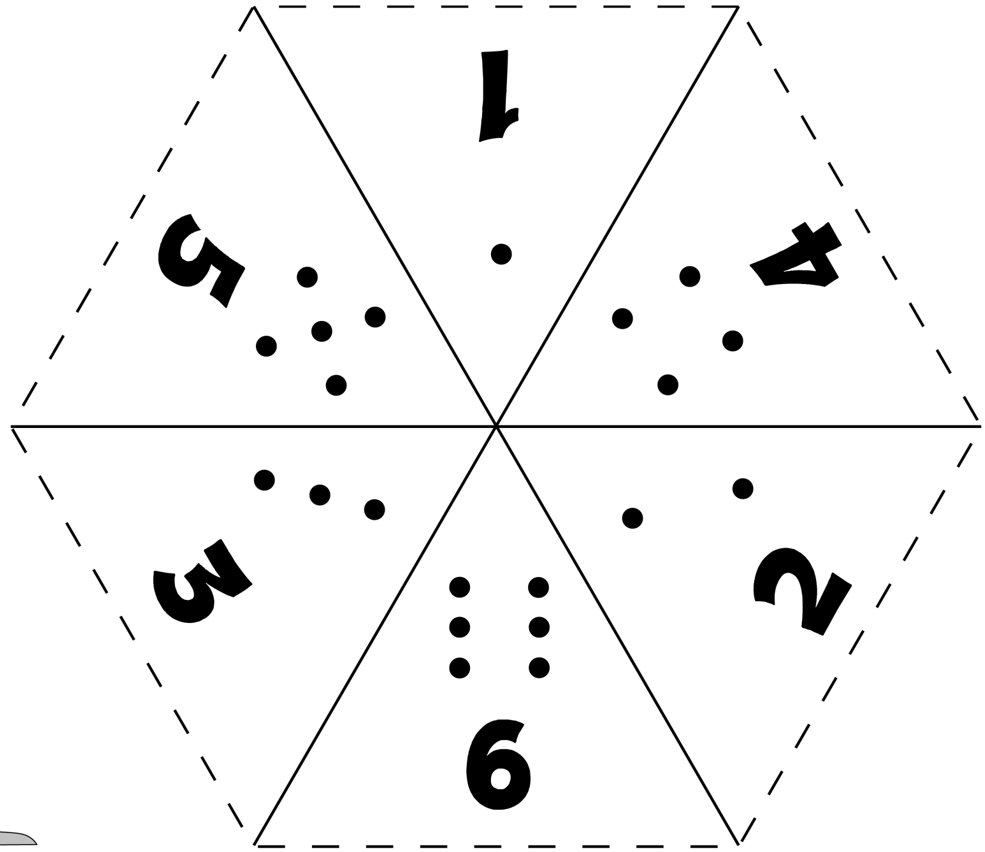


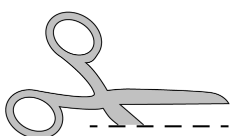
Printable Spinner

Assembly Instructions

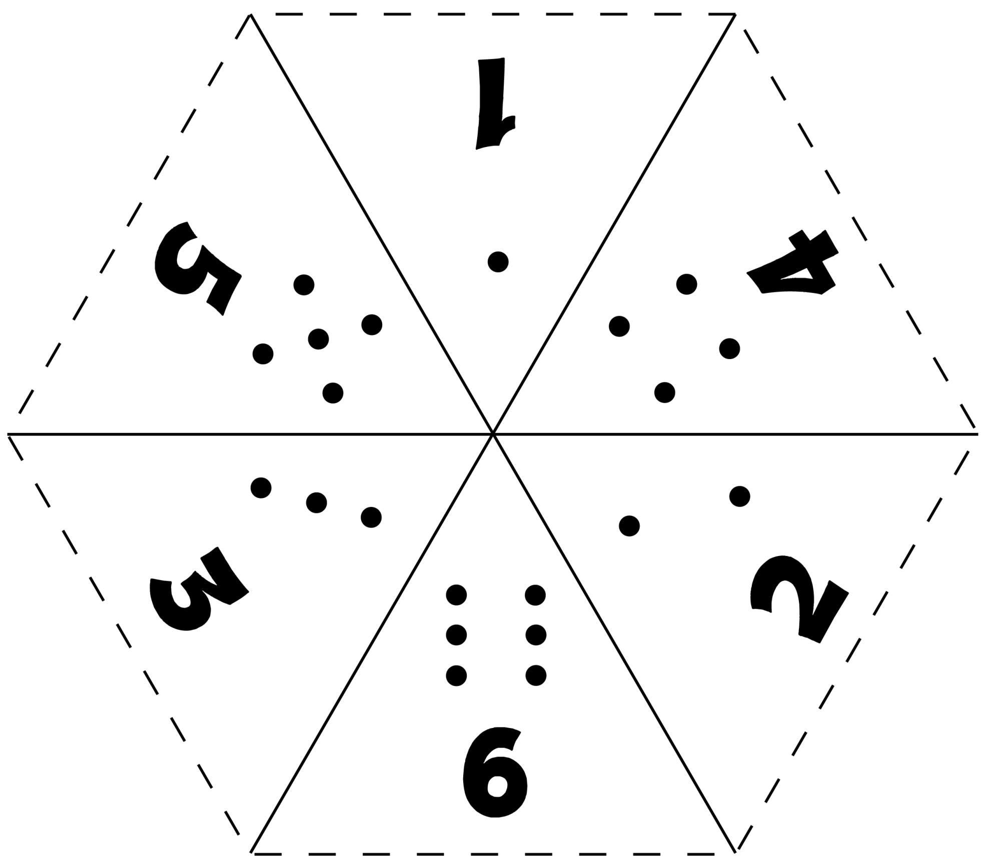


Printable Spinner





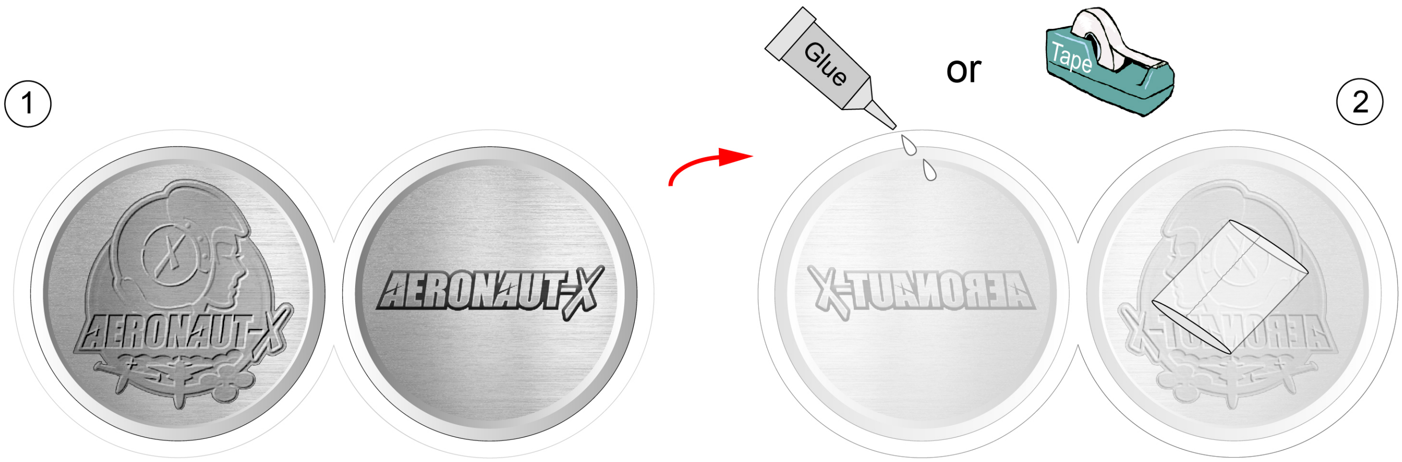
Cut out on dotted line

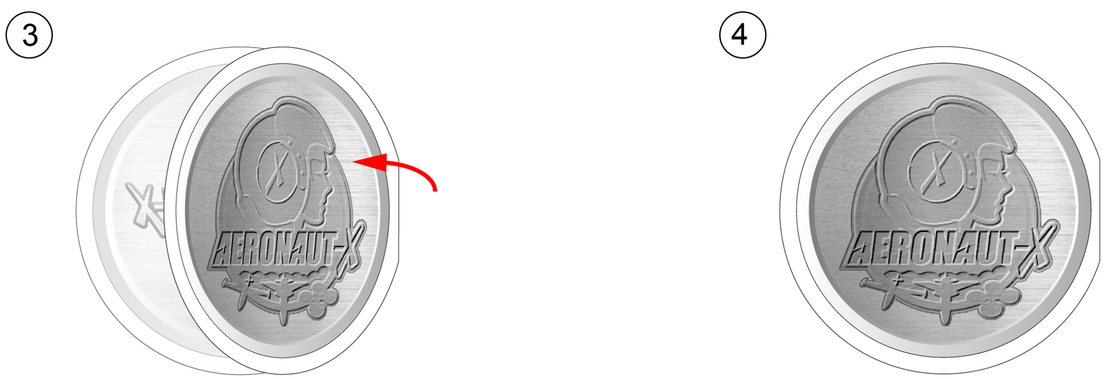


Printable Coins

Assembly Instructions

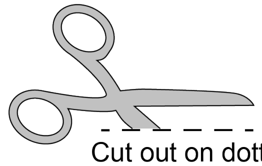
*Glue or tape can be used to assemble coins.



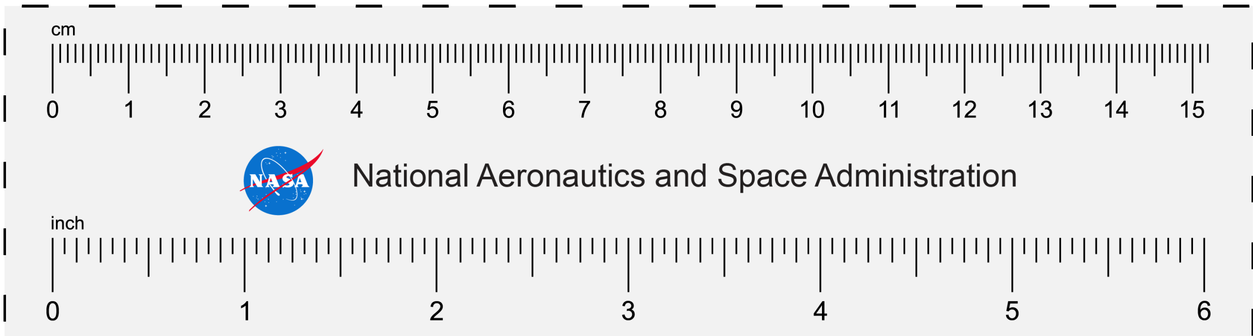


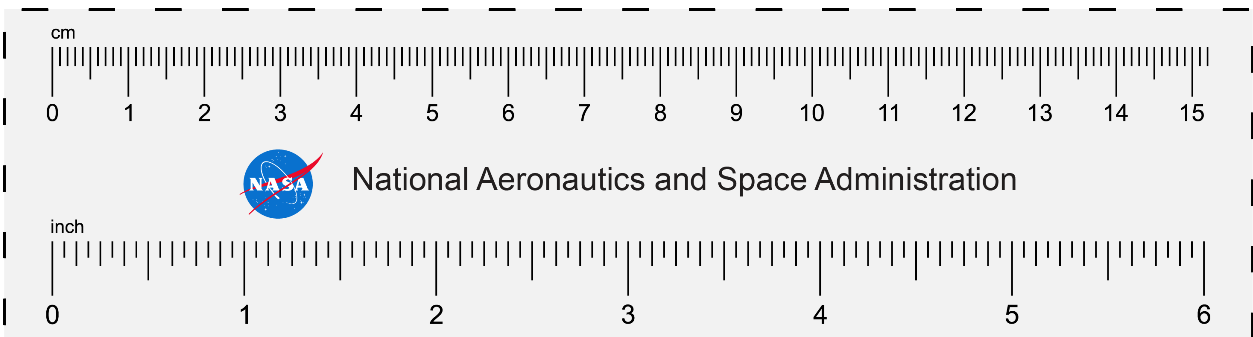
Printable Coins

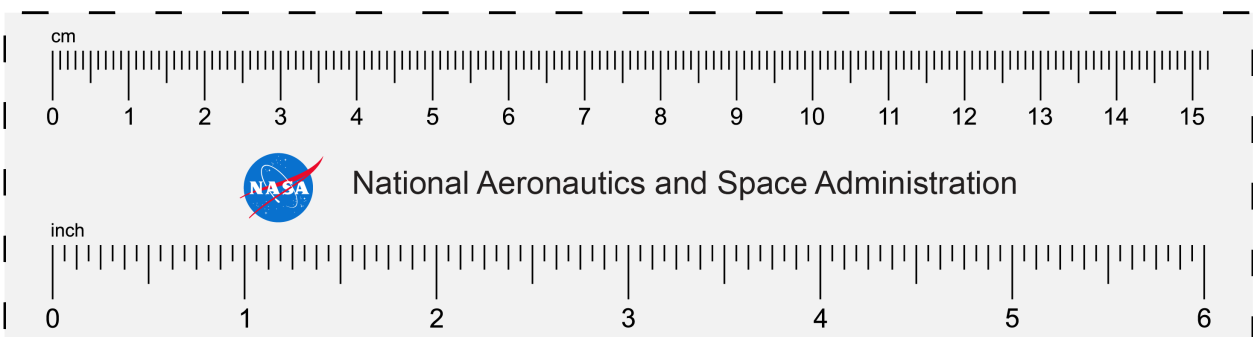
Printable Rulers

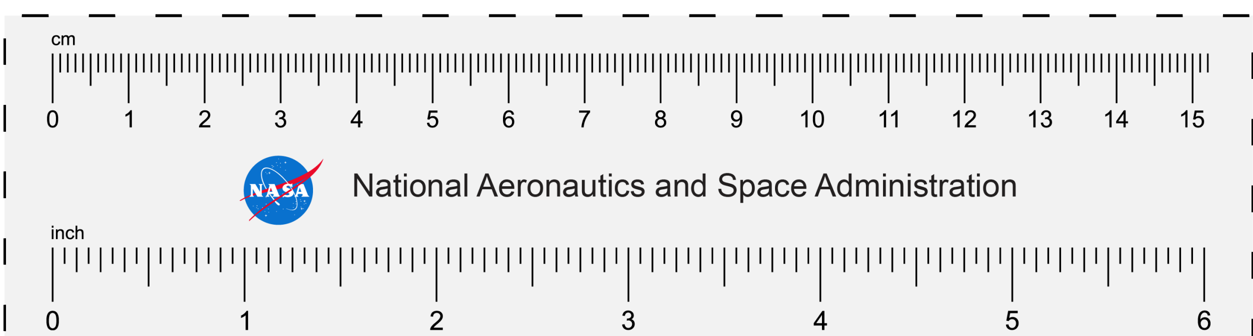


Cut out on dotted line









A.3 Rubric for Problem-Based Learning (PBL)

PBL Step	Novice (0)	Apprentice (1)	Journeyperson (2)	Expert (3)	Level of student knowledge (Score)
Meet the problem	Student does not identify the problem	Student incorrectly identifies the problem	Student identifies part of the problem	Student fully and correctly identifies the problem	
Explore knowns and unknowns	Student does not identify knowns and unknowns	Student incompletely identifies knowns and unknowns	Student identifies knowns and unknowns using experience but uses no resources	Student completely identifies knowns and unknowns using experience and resources	
Generate possible solutions	Student does not brainstorm	Student generates one possible solution	Student provides two solutions	Student provides three or more possible solutions	
Consider consequences	Student does not identify any consequences	Student determines inaccurate or irrelevant consequences	Student identifies consequences accurately	Student identifies consequences accurately and provides a rationale	
Present findings	Student does not communicate results	Student shares random results	Student shares organized results, but results are incomplete	Student shares detailed, organized results with class	
				Total	