

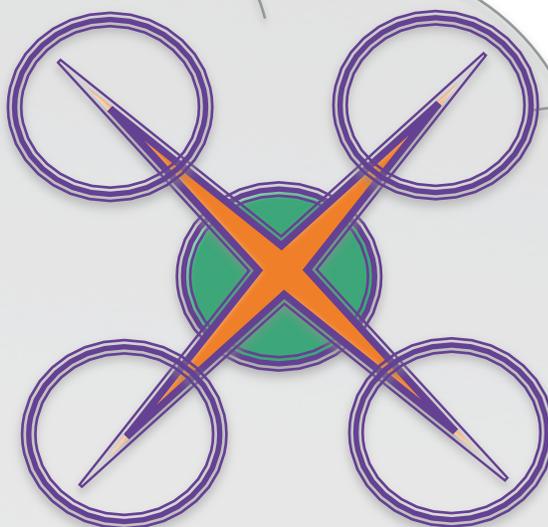
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COOPERATIVE EXTENSION



*How
your
Drone*



4-H NATIONAL YOUTH SCIENCE DAY PROPOSAL

FACILITATOR GUIDE

This document was developed as part of Clemson University's 2016 4-H National Youth Science Day proposal in partnership with Clemson University Cooperative Extension, College of Engineering and Science, and Edisto Research and Education Center. Unless otherwise noted, image credit belongs to Ashley Burns.

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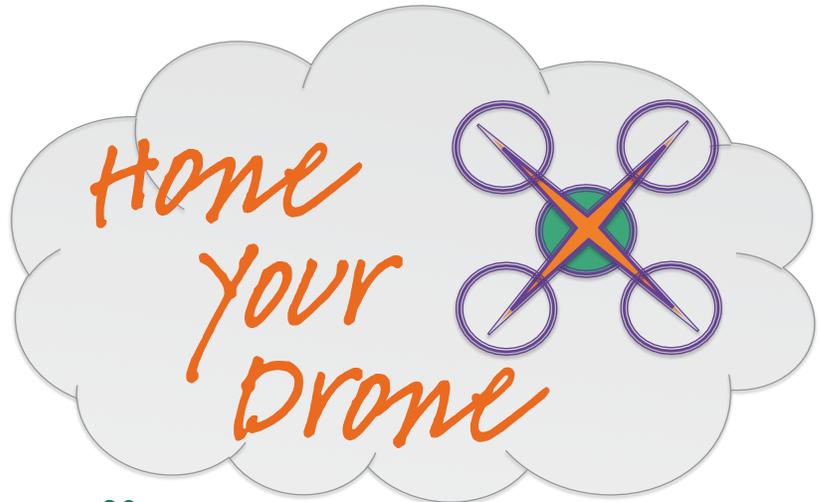
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INTRODUCTION

In October 2016, you will join the nation's largest youth science event: **4-H National Youth Science Day (NYSD)**! Thousands of volunteers and educators from across the country's 109 land-grant universities will help you and millions of other youth learn about drones, as you as you engage in the 9th annual National Science Experiment.

The **2016 National Science Experiment**, *Hone your Drone*, is a design challenge that delves into the science of drones—what they are and how they are used in the real world. You will discover important mapping principles, regulatory and safety information, and engineering concepts.



 **4-H NATIONAL YOUTH SCIENCE DAY**



Drone Image of Clemson University Experiment Station Bull Test
Image Credit: Dr. Matthew Burns

CONTEXT

Though the future of robots is growing, drones are becoming smaller and more versatile. With sophisticated sensors or various attachments drones can perform numerous functions. The potential applications for drones are even more numerous. Photography, disaster relief, and precision agriculture are just a few. To maximize the production and efficiency of crop growth, small drones can hover from plant to plant, dropping just enough fertilizer, lime, water, or spraying exactly the right amount of pesticides to eradicate the weed problems. Use of drones in this manner provides a cost savings to farmer, as well as enhancing environmental stewardship.

A SCIENCE FRAMEWORK FOR K-12 EDUCATION

The *Hone your Drone* NYSD proposal is designed to align with the Science and Engineering Practices defined by *A Science Framework for K-12 Science Education*, the blueprint for developing the *Next Generation Science Standards (NGSS)*, and *Common Core Math* standards.

This activity is appropriate for youth in grades 4 and above.

OBJECTIVES AND OUTCOMES

Youth participating in *Hone your Drone* NYSD challenge will:

1. Develop a basic understanding of drones through hands-on activities that motivate scientific inquiry through the engineering design process and application of mathematic and mapping principles.
2. Analyze future situations and solve real-world issues through creative problem solving.
3. Stimulate interest and gain enthusiasm for a future with STEM education and careers.

USING THIS GUIDE

The facilitator guide for *Hone your Drone* features content found in the Youth Guide and additional information (green boxes) that can assist you in teaching and overseeing each part of the challenge.

safety Tips...

- 1.) Although laundry detergent and salt (included in kit materials) are both household substances, both can cause eye irritation. Laundry detergent is also harmful if swallowed. Therefore, restrict access of these substances to adults only.
- 2.) While illumination from a black light is harmless, everyone should avoid looking directly into the bulb when activated. (Twist to activate.)

WHY DRONES?

Drones are a highly sophisticated combination of **robotics**, **aeronautics**, and **electronics**. Although drones have been around for years, they have only recently become very popular and affordable to the general public. The purchase price of owning your own drone can range from around \$15 to \$100,000 or more! Drones are used by militaries and law-enforcement agencies, scientists, engineers, businesses, and hobbyists. They serve a variety of purposes and impact our lives everyday!

Drones help keep us safe, provide images that we would normally not be able to see, serve as transportation vessels, and even impact the food we eat! Drones are used to monitor traffic conditions and survey crime scenes. They can also be fitted with special sensors and cameras that allow them to see things we cannot. For instance, infrared sensors can detect body heat, which could be used by a drone in the event of a missing person! They can help monitor the health of crops, the food we eat. Drones can offer assistance to remote sites following a natural disaster, such as a hurricane, tornado, or flood (see Appendix 1 about South Carolina's natural disasters of 2015), when roads become impassable or bridges get washed out. They can provide stunning videos of sporting events, fireworks displays, or nature (waterfalls, cliffs, mountains, wildlife, etc.). Some businesses are even promoting the use of drones for package and food delivery!

How cool would it be for your birthday present to arrive via a drone?!

Some companies, like Amazon, are proposing to do just that. In 2013, Amazon announced plans for *Amazon Prime Air*, which is expected to deliver orders within a 10-mile radius of their distribution centers.



GETTING STARTED: WHAT IS A DRONE?

A drone is simply an aircraft without a pilot aboard. They have had many names over the years including “unmanned aerial vehicles”, “remotely piloted aerial systems”, “remote-controlled aerial vehicles”, etc. The **Federal Aviation Administration (FAA)** now calls drones “**unmanned aircraft systems**” (**UAS**). This term includes unmanned aircraft that have highly sophisticated, computerized-autopilot controls or very simple, radio-signal remote controls, like remote-controlled, model airplanes. The United States has the busiest, most complex airspace in the world and the FAA has recently enacted rules help improve the safety of our skies. Everyone who uses a drone that weighs between a half of a pound and fifty-five pounds for recreational purposes has to now register their UAS with the FAA for a \$5.00 fee. For drones weighing more than fifty-five pounds or anyone who uses a drone for business or commercial purposes, special

permission and licensing must be granted by the FAA. Drones that weigh less than half of a pound are exempt from the FAA's registration requirement.

The FAA also has rules stating where you can fly your drone. Many of these rules are common sense practices that should be followed regardless if they were official rules or not.

- *What kind of safety issues can you think of related to drone flight?*
- *What are some sensible rules we should follow when operating a drone?*
- *Should you fly your drone to help first responders in an emergency situation?*

The FAA's Rules for Unmanned Aircraft Systems (UAS):

- All UAS between 0.5-55 pounds must be registered for a \$5 fee.
- Do not fly a UAS
 - Out of eyesight
 - Within 5 miles of an airport
 - Higher than 400 feet above ground level
 - Over private property without permission
 - Over unprotected persons or vehicles

One industry where the use of drones is really taking off is **precision agriculture**. Drones can be used to survey vast areas of crops and, with the use of highly sophisticated sensors, to collect large amounts of data on the status of those crops. As much as we try to manage crops to make them as uniform as possible, there are many factors that can cause variability in crops within a field and between adjacent fields. From their bird's-eye view, drones can measurably detect things we cannot always see with our naked eye, such as the presence of weeds, areas of a field that have too much or too little water, the overall health and growth of the crop, which areas might need fertilizer or lime, and when certain areas of the crop are ready to harvest before the others.



The images above were taken using an infrared camera on a UAS used for precision agriculture research by Dr. Joe Maja at Clemson University's Edisto Research and Education Center. Although it looked normal to the human eye, the UAS was able to detect trouble spots within the field, which are indicated by the circles in the right-hand image. Note the jagged edges of the images due to the scanning pattern of the drone taking multiple photographs; computer software stitches the pictures together to create one large image.

There are 2 main types of UAS:

1. An airplane-style drone is called a “fixed-wing” drone.
2. A helicopter-style drone is called a “rotary-wing” drone.

What are some advantages and disadvantages you can think of for each type of drone?

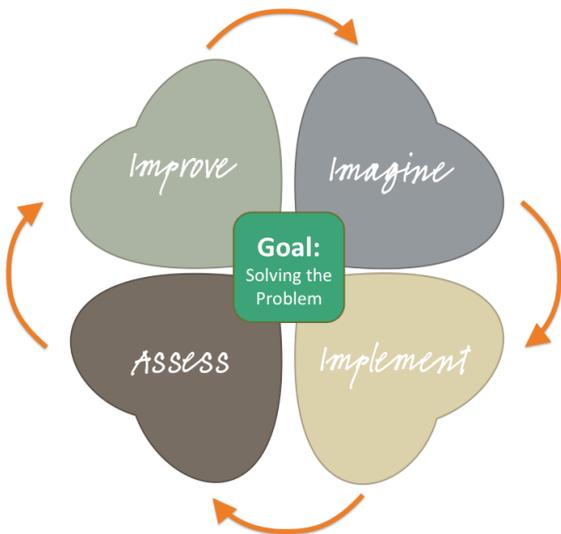
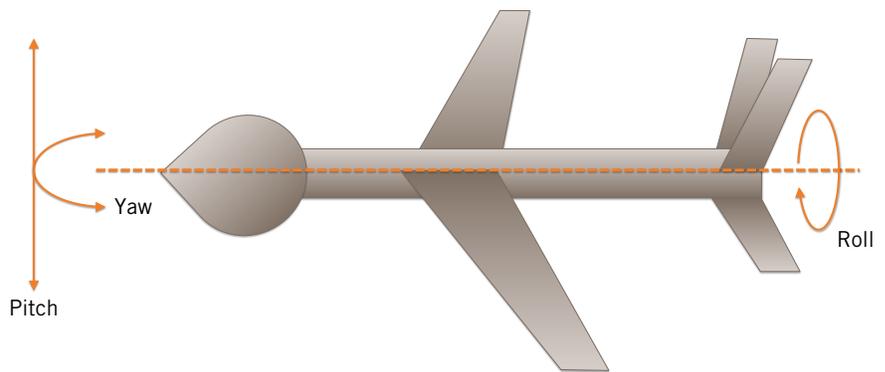
LET’S USE A DRONE TO INVESTIGATE!

There are several parts of a drone that work together to make it functional. A working drone must have a propulsion device (wings or a rotor for lift), a power sources (motor), and a control mechanism (onboard computer, Wi-Fi, or radio-control mechanism). Most drones have some sort of autonomous control, meaning they can control or autopilot themselves to a certain extent.

Global Positioning System (GPS)

can be used to help navigate and stabilize the flight of a drone. There are several ways a drone can move in the air. Yaw, pitch, and roll are terms that can be used to describe the movement in a three-dimensional space. **Yaw** is the side-to-side or lateral change in direction.

Pitch is the upward or downward tilt of the object for changes in **altitude**. And **roll** is the spinning or rotation of an object around a central axis. Have ever wanted to fly a drone? What directional movements are involved and what mapping principles can be used when controlling a drone? How can a drone see differently than us? Let’s use a simulated drone to investigate! **Make sure to think through the design process when completing your challenges.**



<i>Imagine:</i>	Brainstorm ideas, choose one, and make a plan.
<i>Implement:</i>	Put your plan into action.
<i>ASSESS:</i>	Evaluate the effectiveness of your design. <i>Did it work?!</i>
<i>Improve:</i>	Make the best better by revising your design.

THE CHALLENGE

Have you ever spent time weeding a garden? It can be a time-consuming, laborious job. Most gardens that people have at their homes are relatively small and produce only enough food to feed to those that live there for a short amount of time. What if you were responsible for feeding your whole community or school? You would need a really big garden!

The average American farmer produces enough food to feed 155 people for an entire year!!! It takes a lot of land, time, and hard work to achieve that level of production. Because of that, food producers are always looking for ways to help make farming easier and more **efficient**.

Drones are a perfect tool to use in agriculture because they:

- Can cover large areas of land.
- Are much faster than walking or riding on a tractor.
- Require relatively little energy (battery or fuel).
- Are safer for the pilot, who stays on the ground.
- Are relatively inexpensive to own and operate.
- Can perform a variety of tasks with sophisticated software and sensors.

You are now engineers tasked with equipping drones to complete important tasks on an agricultural operation. Imagine that your garden is now 30 acres. There is no way you can weed it by hand, so you choose to apply pesticide to kill any weeds growing in your garden. However, pesticide is expensive and potentially harmful to the environment if not used responsibly. Therefore, you only want to use your pesticide only on areas of your operation that have weeds. First, you must identify where the weeds are. Second, you must treat them with pesticide. Now is the time to work together and **hone** your drone to meet this challenge!



STEP 3: Cut 4 pieces of string approximately 40 inches long. Tie the strings securely to the simulated drone; one string to each corner. Use a yardstick or the grid on the map to mark one-inch increments on each string starting where the string attaches to the drone, which will help you navigate your drone in the design challenges. Note the scale on the map.

With this design, there are several components that are present to make a functional, simulated drone. Using the map and simulated-drone framework, answer the following questions:

- *What serves as the propulsion or lift device?*
- *What serves as the power source?*
- *What serves as the control mechanism?*
- *What distance does 1 inch correspond to on the map?*
- *What does the 8-inch height of the PVC framework represent?*
- *Related to the FAA rules, why is this height significant?*
- *Also related to the FAA rules, what might the strings represent?*



Doing the Math...

The 1-inch squares on the grid represent to 50 feet in real life. The map is 32 inches across and 16 inches down.

Scale Conversion: Length $\frac{1}{50} = \frac{32}{x}$ $x = (32 \times 50) \div 1 = 1600$ feet long

Width $\frac{1}{50} = \frac{16}{y}$ $y = (16 \times 50) \div 1 = 800$ feet wide

Length x Width = 1.28 million square feet

Number of Football Fields on Map: There are 57,600 square feet in a football field.

$1,280,000 \div 57,600 = 22.22$ football fields

Acres represented in the map can be calculated in the same way (43,560 sqft/acre).

DESIGN CHALLENGE 1

DETECTING IN THE DARK

Time Required: 30 minutes

Objective: In this design challenge, you will use the simulated drone to carry a “sensor” across the map to detect and record the location of a “weed infestation” in an agricultural field.

Materials each team will need -

Included in the 2016 NYSD Science Kit:

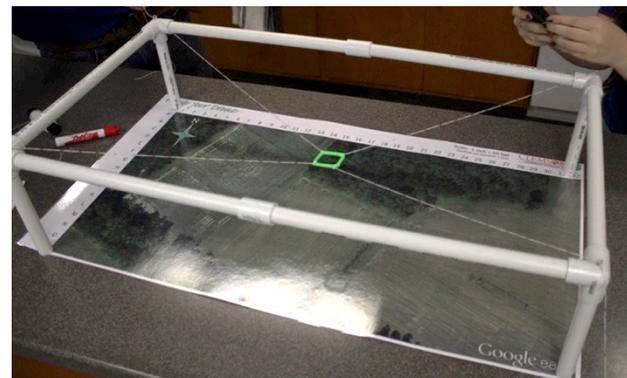
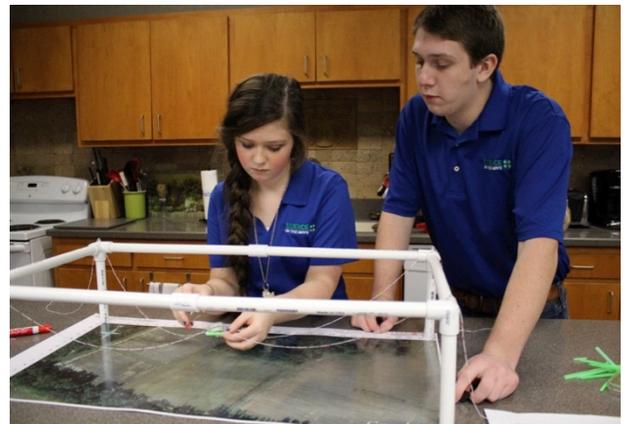
- Simulated drone, framework, and map (assemble according to ‘Building the Basics’ hands-on activity)
- Pipe cleaners
- Black light candle
- Laundry detergent

Not included in the kit:

- Scissors
- Tape
- Paper clips (optional)
- Other miscellaneous office supplies (optional)

STEP 1: Attach the black light candle, which serves as your “sensor”, to your simulated drone. Work as a team to come up with and execute a concept using only the materials supplied in the kit or in your classroom (as allowed by your adult leader). Make sure the bulb faces down towards the map when you attach it to your simulated drone. Thread each string through an eye hook on the corner of the PVC frame. (Hint: Wrapping the string around the hook once or twice will increase the friction between the string and eye hook, which may provide more stability and make the drone easier to control.)

STEP 2: Work together as a team to scan the map with your drone and black light. Prior to doing this, your adult leader will have marked a location on the map with a black light-reactive substance, laundry detergent, to represent weeds infesting the agricultural field. With the lights off or dimmed, systematically scan the map to search for the weed location. Record the coordinates of the weed location using the grid on the map.

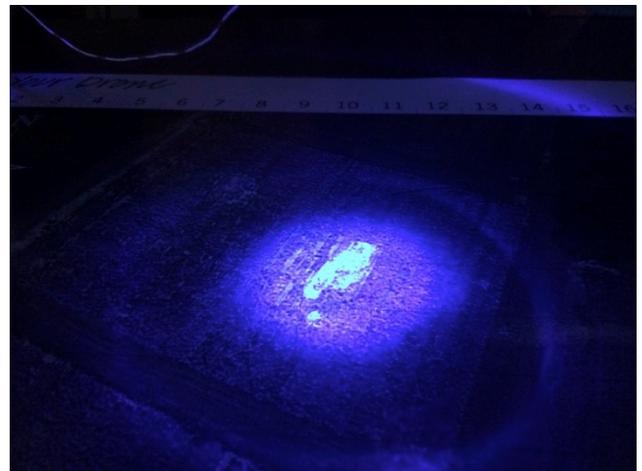
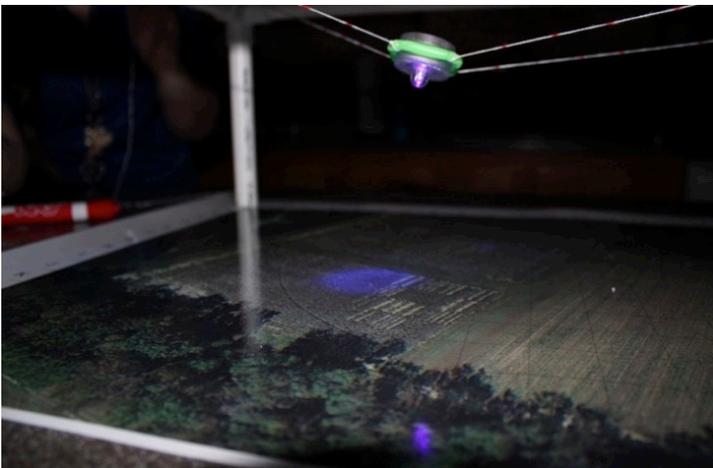


STEP 3: Discuss what you did and observed.

- *Were you able to successfully attach your “sensor” to the drone?*
- *Was it easy to work with someone else to move the drone?*
- *Would you prefer more or fewer people to control the movement of the drone?*
- *What pattern or method did you use to scan the field?*
- *What made you decide to scan the field this way?*
- *Would you choose a different pattern of scanning the field if you repeated the activity?*
- *How did the weeds appear?*

STEP 4: Make connections.

- *How does this black light challenge relate to the use of drones in a real life scenario?*
- *Why would we use drones in this manner?*
- *Besides weeds, what could a drone detect in an agricultural setting?*



Marking the Map...

The map is laminated allowing it to be reusable for multiple NYSD events. In order for youth to complete this challenge, you will need to apply a small amount of laundry detergent to the surface of the map in an area of your choosing. (Do not let the youth see where you put it! You can do this before they arrive or while they are assembling their PVC frames.) The laundry detergent will fluoresce under black light and youth should be able to see it. Although, you may have to dim the lights.

Interesting note...

Although we are only using black lights to represent how drones can see something we cannot and drones do not typically use them, drones could be equipped with black lights! Did you know that water runoff is often tested for grey water contamination using black lights? Inspectors use black lights to see if laundry detergent is present in storm water. If the water glows under a black light, they know there is potentially a source of contamination due to grey water in the area they are inspecting.

DESIGN CHALLENGE 2

KILLING THE KUDZU

Time Required: 30 minutes

Objective: In this design challenge, you will use the simulated drone to pick up, transport, and apply a “pesticide” to the weed location you recorded in Design Challenge 1. You will calculate the distance your drone will travel to the targeted destination using mathematics and geometry, design a transportation device, and execute delivery of the pesticide to the target destination.

Materials each team will need -

Included in the 2016 NYSD Science Kit:

- Simulated drone, framework, and map (assemble according to ‘Building the Basics’ hands-on activity)
- Pipe cleaners
- Petri dish (one side)
- Salt

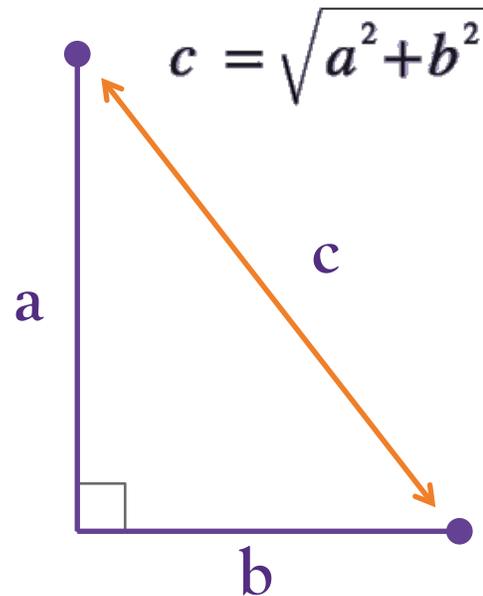
Not included in the kit:

- Scissors
- Tape
- Calculator
- Index cards (optional)
- Binder clips (optional)
- Paper clips (optional)
- Other miscellaneous office supplies (optional)

STEP 1: Work as a team to calculate the distance your simulated drone will travel from a start location to the target destination that you identified in Design Challenge 1. One side of a petri dish filled with salt, which represents your pesticide, will be taped to the surface the map by your adult leader. First, record the location of the center of the petri dish and use it to calculate the distance you need to travel from your start point to your target destination.

STEP 2: Work as a team to design and construct a device that you can pick up, transport, and deliver salt from the petri dish to the target area on the map you detected in Design Challenge 1. Use only the materials you have supplied in the

Pythagorean Theorem



Calculating the distance the drone will travel between 2 points is just like calculating the hypotenuse of a right triangle! Use the Pythagorean theorem above to calculate your distance. The grid on the map will give you vertical and horizontal distances for *a* and *b*.



kit or in your classroom (as allowed by your adult leader) to complete this challenge.

STEP 3: Using the device you created in step 2, pick up, transport, and deliver salt from the petri dish to the target area. When moving the drone for this challenge, note the number of 1-inch marks on your strings that pass through the eye hooks at each corner of the PVC framework.

STEP 4: Discuss what you observed.

- *Were you able to pick up your pesticide? Why or why not?*
- *Were you able to successfully transport your pesticide on the target? Why or why not?*
- *Were you able to successfully deliver your pesticide on the target? Why or why not?*
- *Were you able to control the yaw, pitch, or roll of the drone?*
- *How can you adjust the design your collection device to more effectively execute your task of applying pesticide?*
- *How did the number of inches you pulled or released on the strings relate to the distance you calculated that your drone would travel?*

STEP 5: Make connections.

- *Why might it be important to apply pesticide in a targeted area instead of applying it to an entire field?*
- *Why would pre-planning and programming a route be important for working with a drone?*
- *What other things could be transported using drones? (non-agricultural)*
- *If you were standing in this field in real life at coordinates (F,25), could you fly your UAS in the area of (B,12)? Why or why not?*

It is important for the youth to understand that the transportation applications for drones are virtually endless. Drones could be used to transport any number of things related to agricultural and non-agricultural purposes, including delivery of food, water, and medical supplies following a natural disaster, vaccines and life-saving equipment to remote areas of the world, or something more mundane like delivering pizza! What would youth in your NYSD group use a drone for?!

Doing the Math...

The Pythagorean theorem is the geometrical formula used to calculate the diagonal edge of a right triangle.

Example: If you youth move their drone in a straight line from coordinates (B,7) to (F,15), they can count squares on the grid to determine that they will move 4 inches down and 8 inches across.

4 inches down = a

8 inches across = b

$$c = \sqrt{a^2 + b^2}$$

$$= \sqrt{4^2 + 8^2} \quad \text{or} \quad = \sqrt{(4 \times 4) + (8 \times 8)}$$

$$= \sqrt{16 + 64}$$

$$= \sqrt{80}$$

The distance the drone will travel is = 8.9 inches = c

CONCLUSIONS

Drones are used in a variety of circumstances and perform a variety of functions that affect our daily lives. They provide a fast, efficient method of transportation, surveillance, videography, and more! Piloting a drone is a big responsibility and it is important for drone operators to be aware of the safety rules and regulations applying to drones. Understanding the way in which drones work is key to unlocking their potential. The areas of commercial and agricultural use of drones is rapidly expanding and opening the skies to a bright future for scientists, engineers, and others interested in exploring what this technology can bring us!

Did you know...?!

One of the world's smallest drones is a remote-controlled quadcopter that measures only 2 inches across and weighs 0.2 lb.

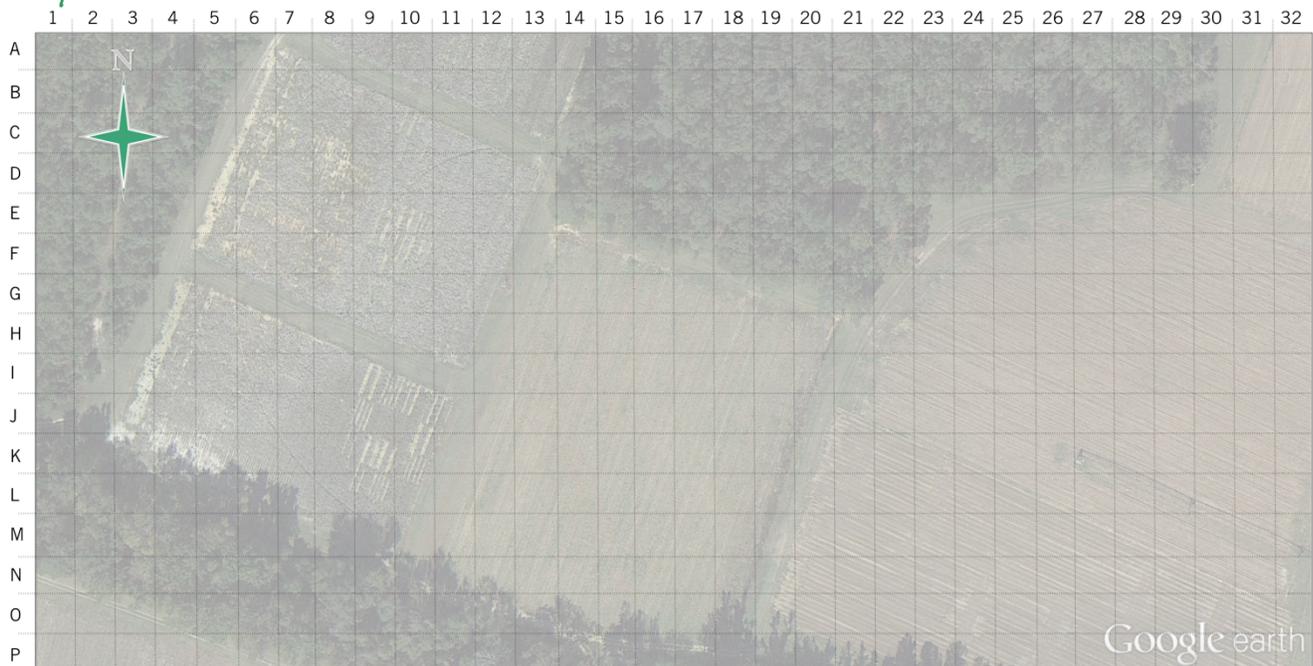


One of the world's largest drones is the IAI Eitan, a military reconnaissance drone. Its wingspan is 86 feet across and can weigh over 10,000 lb at takeoff! That is bigger than some airplanes.

NOTES

Use this area to record your coordinate information, design notes, and calculations. Draw the location of your weeds and pesticide pick-up site on the map below.

Hone your Drone



DEFINITIONS:

Aeronautics - aer·o·nau·tics, erə'nôdiks/ *noun*

the science or practice of travel through the air.

Agriculture – 'agrə,kəlCHər/ *noun*

the science or practice of farming, including cultivation of the soil for the growing of crops and the rearing of animals to provide food, wool, and other products.

Altitude - 'altə,t(y)ōōd/ *noun*

the height of an object or point in relation to sea level or ground level.

Drone – drone, drōn/ *noun*

a remote-controlled pilotless aircraft or missile.

Efficiency - ə'fiSHənsē/ *noun*

the ratio of the useful work performed by a machine or in a process to the total energy expended.

Electronics – e·lec·tron·ics, ə,lek'trāniks/ *noun*

the branch of physics and technology concerned with the design of circuits using transistors and microchips, and with the behavior and movement of electrons in a semiconductor, conductor, vacuum, or gas.

Federal Aviation Administration (FAA) – *noun*

the national aviation authority of the United States. As an agency of the United States Department of Transportation, it has authority to regulate and oversee all aspects of American civil aviation.

Global Positioning System (GPS) – *noun*

a radio navigation system that allows land, sea, and airborne users to determine their exact location, velocity, and time 24 hours a day, in all weather conditions, anywhere in the world.

Hone – hōn/ / *verb*

to refine or perfect (something) over a period of time.

Pitch – piCH/ *verb or noun*

verb: (of a moving ship, aircraft, or vehicle) to rock or oscillate around a lateral axis, so that the front and back move up and down.

noun: (of a moving ship, aircraft, or vehicle) rocking or oscillation around an axis parallel to the direction of motion.

Precision Agriculture - *noun*

a farming management concept based on observing, measuring and responding to inter and intra-field variability in crops.

Robotics - ro·bot·ics, rō'bādiks/ *noun*

the branch of technology that deals with the design, construction, operation, and application of robots.

Roll - rōl/ *verb or noun*

verb: to move or cause to move in a particular direction by turning over and over on an axis.

noun: a swaying or oscillation of a ship, aircraft, or vehicle around an axis parallel to the direction of motion.

Unmanned Aircraft System (UAS) – *noun*

an aircraft without a human pilot aboard, also known as a drone.

Yaw – yô/ *verb or noun*

verb: (of a moving ship or aircraft) to twist or oscillate about a vertical axis.

noun: a twisting or oscillation of a moving ship or aircraft around a vertical axis.

APPENDICES - Supplemental Information & Activities

1.) SOUTH CAROLINA 2015 NATURAL DISASTERS

Last year, 2015, was a very difficult year for farmers in South Carolina. The year began with a record drought. United States Department of Agriculture declared primary natural disaster areas in 35 of South Carolina's 46 counties, which more than 76% of the counties in the state! Then, in October 2015, South Carolina experienced historic flooding that poured over 27 inches of rain in some areas in one weekend. This time, 29 counties were designated primary natural disaster areas by the USDA. Homes, roads, bridges, dams, and farms were lost. Nineteen people also lost their lives in the flood. Drones were extensively used by residents, news organizations, and scientists to document and visualize the damage caused by natural disasters in 2015.

Overview of the flooding effects on South Carolina farmers:

<http://newsstand.clemson.edu/mediarelations/clemson-documents-impact-of-drought-historic-flood-on-farmers/>

<http://www.clemson.edu/extension/scflood/>

Drone video footage of an area impacted by the flood:

https://www.youtube.com/watch?v=b-7wLVRW_sQ

2.) SUPPLEMENTAL ACTIVITIES

There are numerous activities that you could do using this set up that would enhance your learning experience. *How would drones benefit a livestock operation?* They could inventory and locate animals, deliver feed, monitor animal health, and much more. *What about non-agricultural businesses?* Transport and delivery services are a huge, emerging market for drones. *What are some other ways you could use this project?!* Let your imagination soar!

ROBOTICS

Focus on exploring robotics

Use the PVC framework as the platform for a robotic-controlled device. Apply programming and mapping principles to this activity to take off in a whole new direction.

COMPETITION

Drone Racing

Drone racing has become a popular activity recently. Plot a course or set a series of tasks to complete; whichever team performs the best, wins! The design challenges themselves can serve as competition platforms for timed or head-to-head competitions using one or more NYSD kits.

CALCULATING COORDINATES

Mapping principles

Latitude, longitude, and GPS coordinates can be very confusing if you are not familiar with working with them. They tell you essentially the same thing, but the way in which the numbers

are presented differ. Latitude and longitude are often written numbers as degrees, minutes and seconds; whereas, GPS coordinates are numbers written with a decimal. This table below shows the precision of various units at the northern U.S. region. The distance of one degree of longitude changes depending on where you are in relation to the Earth's poles. One degree longitude is approximately 69 miles at the equator and 0 miles at the poles. In the northern US region, it is about 42 miles. One degree of latitude stays the same; it is always about 69 miles. Traveling north of the equator results in a positive GPS coordinate number, but traveling west of the Prime Meridian results in a negative GPS coordinate.

	Latitude	Longitude
1 degree	69 miles	42 miles
1 minute	6072 ft	3696 ft
1 second	101.2 ft	61.6 ft

Decimal Degrees	Latitude	Longitude
0.1	36432 ft	22176 ft
0.01	3643.2 ft	2217.6 ft
0.001	364.32 ft	221.76 ft
0.0001	36.43 ft	22.18 ft
0.00001	3.64 ft	2.22 ft
0.000001	4.37 In	2.66 In
0.0000001	0.44 In	0.27 In

Assuming the latitude and longitude coordinates for (A,1) are $33^{\circ}21'25.2''N$ by $81^{\circ}19'01.4''W$, what would the GPS coordinates be? **Answer: 33.357007, -81.317060**

Also calculate the bearing, the distance you would travel, and the new map coordinates if you were to travel to $33^{\circ}21'22.42''N$ by $81^{\circ}18'56.72''W$. (Information on how to calculate distance and bearing using latitude and longitude can be found at: <http://www.movable-type.co.uk/scripts/latlong.html>)

On the map, what object appears to be present at your destination?
Answer: The center pivot of the irrigation system!

3.) REGISTER YOUR DRONE

If you have a drone that needs to be registered with the FAA, visit <https://registermyuas.faa.gov> for more information and online registration.

