USING RECREATIONAL UAVS (DRONES) FOR STEM ACTIVITIES AND SCIENCE FAIR PROJECTS

Education Committee
Federation of Earth Science Information Partners

Presenter: Shelley Olds, UNAVCO
ESIP is an open, networked community that brings together science, remotely sensed data and information technology practitioners.

ESIP EDUCATION
Curriculum developers, instructors, evaluators, and educators who promote the use of Earth Science data for learning
UAVs 4 STEM: Two Webinars and Workshops

Webinar 1: March 2, 2016
UAVs 4 STEM
Learn about real-world uses of drone technology for science and humanitarian efforts. Find out how you and your students can use recreational drones for STEM learning.

Webinar 2: April 26, 2016
Plan, Fly, Review: Documenting Drone Data
Get organized so you can learn something from every UAV flight. Learn best practices for documenting your flights, images, and science data.

Workshop: July 19, 2016 Chapel Hill, NC
Test and Refine STEM Learning Activities
Fifteen successful applicants will receive a drone and a $200 stipend to test and refine activity ideas, and then use them with youth in the fall. The workshop will prepare attendees to facilitate drone-based STEM learning in clubs, classrooms, or science fair activities.

Using Recreational UAVs (Drones) for STEM Activities and Science Fair
Engage students in STEM using the “it” toy of the year: Unmanned Aerial Vehicles (UAVs or drones)! Try free teacher-developed activities for STEM learning.
Recreational drones

- weigh less than a half pound
- do **not** need to be registered with the Federal Aviation Administration (FAA)
- usually cost less than $100
- can be considered as “toys”
- Must be within sight

AKA …

- Unmanned Aerial Vehicles or UAVs
- Unmanned Aircraft Systems or UASs
- Quadcopters / Quadrocopters
- Multi-rotors / Helicopters
- Fixed-wing drones
- Aerial robotics
ESIP Education UAV GOALS

- Downloadable e-book of STEM activities using recreational drones
- Cadre of educators to facilitate activities & data management strategies
- Opportunities for follow-on data explorations with ESIP members
Survey Results: Teacher Interest in Using Drones

- How to use them to collect images or other data (84%)
- How professionals are using them in various fields (71%)
- In after-school clubs (84%)
- In science classes / sessions (61%)
Our main goal: help educators facilitate STEM learning.

As we can’t cover everything about drones, we made a conscious decision to omit:

- Teaching people how to fly drones (lots of resources for flying already exist)
- Flying drones for commercial profit or a business (these activities require special licenses)
- Building and / or coding drones (great activities, but out of our scope)
Experience new perspectives and new challenges: Merges science, technology, and data science.

Build critical thinking skills by asking questions, brainstorming ideas, planning & carrying out investigations, analyzing & explaining the data.

Work in a team: each person has a role.

Provide hands on experiences about science and reproducibility of results - translates to abstract thinking.

How have you convinced your administration?
SAFETY & CIVILITY FIRST!

- Avoid wind.
- Develop skill by practicing at low altitudes. [Waist-height]
- Fly only in safe places: set and observe boundaries that keep you and your drone clear of traffic and other hazards.
- Be alert! Don’t let enthusiasm overcome common sense.
- Whenever you perceive potential dangers, stop and change the situation.

- Follow the Golden Rule when choosing a location to fly.
- Consider if you would (or could be concerned about seeing a drone in particular situations.
- If the site of a drone is likely to disturb people or wildlife, don’t fly there.
Know Before You Fly
Free for iOS & Android.
Check for specific restrictions in parks, near sensitive facilities, and places where you might disturb wildlife.
BEFORE GOING OUTSIDE: ASK QUESTIONS -&gt; MAKE A PLAN

NGSS: Ask questions and define problems
   Pick a question that you want to try answering with your drone.

NGSS: Developing and using models
   Draw a diagram illustrating your hypothesis.

NGSS: Planning and carrying out investigations.
   What do you want to accomplish this flight session?
BEFORE GOING OUTSIDE: ASK QUESTIONS -> MAKE A PLAN

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**NGSS: Planning and carrying out investigations.**
- What do you want to accomplish this flight session?

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**Where do you plan to fly?**

**What equipment do you need?**
- Safety glasses,
- Drone(s),
- Extra batteries,
- Repair kit,
- Hand-held camera, other sensors,
- Science notebook / Log-book, etc.

**Science Teams:**
- pilot / spotter / data recorder
## PLANNING: THE SCIENCE / FLIGHT TEAM & ROLES

### Data Recorder Roles:
- **Pre-flight**
  - Calls out pre-flight checklist items
  - Completes the Flight Datasheet
- **In-flight**
  - Reads out investigation instructions
  - Fills in data collected during flight
- **Post-flight**
  - Calls out post-flight checklist

### Spotter/Safety Lead Roles:
- **Pre-flight**
  - Describes weather data
  - Checks surroundings for obstacles & hazards
- **In-flight**
  - Keeps drone in site
  - Scans surroundings
  - (optional) Reads off data to recorder
- **Post-flight**
  - Retrieve the drone.

### Pilot Roles:
- **Pre-flight**
  - Checks the drone
  - Checks instruments/sensors
- **In-flight**
  - Flies the drone - follows investigation instructions from Data Recorder
  - Keeps drone in site & lands safely
- **Post-flight**
  - Turns off drone, etc.
PRE-FLIGHT CHECKLIST: BEFORE EVERY FLIGHT

Data Recorder: Read this checklist aloud, asking for the confirm / data from Spotter & Pilot.

Spotter/Safety Lead:
- Weather conditions of flying area:
  (Cloud Cover (%), Temperature, wind direction, speed, variability, humidity (optional))
- Hazards present? (yes/no/describe)
- Takeoff/landing area established?

Science focused checklist: TBD by the investigation

Pilot:
- Drone checks:
  Spin your props - secured? Check for loose parts. Battery is charged & connected. (opt)
  Payload secured?
- Transmitter checks:
  Battery is charged, Joy-sticks work.
- Instrument checks:
  Camera: Connected to power? SD card inserted? Sufficient storage available?
  Other sensors & equipment: Power on? memory card inserted? Sensor working? Secured to drone? Meter-circle in place?

Everyone:
- Step back 5x5 for safety
Before you fly

**STOP**
- Put your drone down.

**Take 5 steps back.**

**Look around for 5 seconds.**
- Look behind you too!
- **IDENTIFY & ASSESS hazards, MAKE CHANGES if needed, SAFELY** – complete your flight

Instructor: Data scribe - see anything?
Spotter - see anything?
Pilot - See anything?

Stop to address anything you see.

Instructor: Team, start your flight!
Session Number:

Date:

Instructor:

Location: Address/City/State, football field, south playground etc.

Describe your site - Flat/slope? trees - shrubs

GPS location (optional): lat, long, elevation

Drone & transmitter information: Make / model / battery type & number

Weather conditions: Cloud Cover (%), Temperature, wind direction, speed, variability, sun direction, humidity (optional)

Potential dangers and plan for handling each.

Flight Number:

Time of takeoff:

Names: Pilot / Spotter / Data recorder:

Goal for this flight:

Battery number / Flight duration:

File names / Folder name of images/video taken from ground / in-flight.

Observations:

How did flight end? (Crash/soft/etc)

Flight path / altitude description:
Using Recreational UAVs (Drones) for STEM Activities and Science Fair Projects

Free downloadable eBook - now in Draft form!

Google search for: ESIP Drone Activities

http://wiki.esipfed.org/index.php/ESIP_Drone_Activities

Federation of Earth Science Information Partners (ESIP) Education Committee
Time to Fly!

https://www.youtube.com/watch?v=S1afHu8phlc
Sample Activity Idea: [Drone-only experiment, testing physical properties]

**What payload can my UAV carry?**

Materials: Set of washers or bolts
String
Balance, or a food or postal scale

Can your drone carry and fly with a small sensor that measure environmental conditions such as temperature, air pressure, and location?

<table>
<thead>
<tr>
<th>Sample Data Table</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Mass</td>
</tr>
<tr>
<td>Ability to launch (good, fair, poor, fail)</td>
</tr>
<tr>
<td>Ability to maneuver (good, fair, poor, fail)</td>
</tr>
<tr>
<td>Payload mass</td>
</tr>
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</tbody>
</table>
**FLIGHT SESSION DATA**

**SCIENCE DATA**

### Drone Flying Session

29 Jan 2016  
Weather: Sunny, calm
Back porch at 9321 E Mallard St  
 Mesa A2
Flat patio + yard, cactus beyond.

**Drone Model:** Propel Altitude 2.0  
**Battery:** A + B, weigh interchangably

**Pilot:** B Bundy  
**Recorder:** LDahman

**Activity:** What payload can my UAV Carry

**Notes:**
Taking off from a bench atop a wide plastic cup helped facilitate take off. Otherwise, the drone was flat sitting atop the attached weights.

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### Drone Activity Testing 29 Jan 2016

L Dahman  
B Bundy

What mass of payload mass can my drone carry?

<table>
<thead>
<tr>
<th>Mass (g)</th>
<th>Ability to launch</th>
<th>Ability to recover</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>Quick</td>
<td>Good</td>
</tr>
<tr>
<td>50</td>
<td>Quick</td>
<td>Good</td>
</tr>
<tr>
<td>100</td>
<td>Quick</td>
<td>No results</td>
</tr>
<tr>
<td>150</td>
<td>Fail</td>
<td>Fail</td>
</tr>
<tr>
<td>125</td>
<td>Fail</td>
<td>Fail</td>
</tr>
<tr>
<td>112.5</td>
<td>Struggler</td>
<td>Poor</td>
</tr>
</tbody>
</table>

Total weight:
- 1st test: 757.6g
- 2nd test: 1308.1g

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How high can my drone fly?

If your drone doesn’t have a GPS unit, how can you figure out how high you’re flying?

The Challenge:
Design and perform one or more experiments to help you identify a way to estimate your drone’s height. Use your experience to judge which method provides the most accurate estimates.

Suggested materials
- Football or soccer field with marked distances or measuring tape
- Angle-measuring app on a smartphone
- OR
- Protractor inclinometer (find instructions online to make your own)
- Scientific calculator

Suggested Procedure
Set up a flight zone so the drone pilot and observer are a known distance apart. For instance, you might place yourselves on a sports field so you are 10 yards (30 feet) apart. Record your measurement on a data table.

Pilot: Fly the drone straight up and hover directly overhead at the height you want to measure.

Observer: Use a level app on a smartphone (or a make and use a simple inclinometer) to
1) Measure and record the angle to the drone—you'll use this value to calculate the height of the drone above your eye level.
2) Measure and record the angle to the spot directly below the drone—you'll use this value to calculate the height of your eye above the ground.
3) Use the angles and formulas (which use the tangent function [tan] on a scientific calculator) to calculate the height of the drone above the ground.

Distance from pilot to observer

<table>
<thead>
<tr>
<th>Example</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 feet</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Observed angle to drone

<table>
<thead>
<tr>
<th>Example</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>43°</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Observed angle to the location directly below the drone

<table>
<thead>
<tr>
<th>Example</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>10°</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Calculation

- (Tan(a) x distance from pilot to observer) + (Tan(b) x distance from pilot to observer) = Drone height above ground

<table>
<thead>
<tr>
<th>Calculation</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Tan 33° x 30 feet) + (Tan 12° x 30 feet) = (19.5 feet) + (5.3 feet) = 24.8 feet</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Drone Height

<table>
<thead>
<tr>
<th>Example</th>
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<th>Trial 3</th>
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<td>24.8 feet</td>
<td></td>
<td></td>
<td></td>
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</table>

Think it through:
How many trials will it take for you to feel confident your final answer is accurate?
How might you check if your answer is reasonable?
What can you do with the information of how high your drone is?
How else might you use the technique you used to estimate height?

Present your results.
You may want to discuss answers to the Questions to Consider as part of your results.
How high can my drone fly?

Side A = \( \tan(\angle a) \times \text{horizontal distance from drone} \)

Side B = \( \tan(\angle b) \times \text{horizontal distance from drone} \)

Spot on ground directly below drone
Collecting Data: Drone cameras can generate lots of data

For Example:
Static images:
1 drone
1 image per minute
5 minutes of flight
× 20 flights
100 images

Using old math notation
Collecting Data: from video

Static images:
1 drone
1 image/min
5 minutes of flight
× 20 flights
100 images

Video:
1 drone
5 minutes of flight (x 60 sec)
24 frames per second
× 20 flights
144,000 images!
A 3D View from a Drone

The Challenge:
Design and conduct an experiment to make a 3-dimensional image.

Ex: an outcrop to study the rocks and view where vegetation is growing on the outcrop.

The Challenge:
Design and conduct an experiment to make a 3-dimensional image of an outcrop to study the rocks and view where vegetation is growing on the outcrop.

Steps:
1. Ask a question that you want to try answering with your drone.
   What can we learn about the rocks we see that affect this rock outcrop?

2. Create a model using the following:
   Draw a diagram that shows what you plan to build and how it will look.

3. Create a concept based on your project question.
   - Rocks, paper, construction paper. Make a model of the rocks and vegetation.

4. Plan your investigation. Think through what you want to know. What will you do to collect the information you need?
   - Suggested materials:
     - Draw with a camera:
       1. One-meter cube or square block on the ground (cloths or tape)
     - Photographs:
       - Capture your rock outcrop:

5. Design your experiment.
   - What will you do to test your hypothesis?
   - What variables will you change or measure?

6. Communicate your results.
   - What did you learn from your experiment?
   - How do your results support your hypothesis?

7. Additional project options:
   - How could you use your project in other ways?
   - What would you change if you could do the experiment again?
WHAT'S THE FIELD OF VIEW?

H O W  C A M E R A  D R O N E S  W O R K

Drones can provide information on vegetation, ice cover, flooding, and more!

**FLIGHT CONTROL**
Software determines if the motors need more or less power to keep the drone steady.

**RADIO CONTROL**
Controllers tell the drone what to do via radio signal. The drone can be told to fly faster, descend, etc.

**NAVIGATION**
GPS and a barometer, which measures atmospheric pressure, tell the flight control software where the drone is located and how it can return to home base.

**CAMERA**
A camera can record and send video. The camera stays focused on the target while the drone flies.

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**Syma X5HW recreational drone**

- **Max Flight Time**: 7 minutes
- **Operating Range**: 50 meters
- **Still Camera Resolution**: 2 megapixels

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PLANNING THE OVERLAP OF PHOTOS

NSTA sign
These are 3D models!
GEODETIC IMAGING … GEODESY W/ GPS

Tectonic Motions of the Western United States

Guiding questions as you explore

1. In general, what direction is the land moving overall (directions that the vectors point) in the Pacific Northwest, Basin & Range, and California? How are the motions similar and different between the regions? What does this indicate?

2. For each region, describe how the velocity of the land changes such as similar direction but with very different in length (speeds) or different directions from each other
   - From the coast to inland,
   - On top of near a plate boundary (heavy yellow lines on map),
   - From one side of a state to another, and/or
   - From north to south.

- Use the vector scale bar to make measurements. Measure some of the motions in terms of the vector speed (the lengths of the vectors) and write the measurements them below.
- Sketch in and label two to four representative vectors for each of the regions below. Show general map location and velocities, and directions

   - Pacific Northwest (Washington / Oregon / Northern California region)
   - Basin & Range (Nevada / Utah region)
   - California (Which side of the plate is moving faster?)
TIME TO FLY!

Pilot:
1. Announce out loud – “CLEAR PROPS”.
2. Make sure the throttle (left stick) is all the way down.
3. Turn on the transmitter.
4. Back away 3 or 4 steps (or to a safe distance).
5. Bind & calibrate drone
6. Take test photo and video
7. Announce out loud – “TAKE OFF”.
8. Launch drone
9. Keep facing the quadcopter the entire time.
10. Maintain a safe altitude when flying over buildings / obstacles
11. Keep a direct line of sight at all times when flying

Data scribe:
1. Call off take out list
2. Start a stopwatch (app)
3. Take notes
4. Keep an eye on the drone too

Spotter:
1. Move around so you can always see the drone.
2. Continually scan the flight and ground areas for potential hazards.
Thank you for attending!
education @ unavco.org
olds @ unavco.org