A 3d View from a Drone: Make a 3d model from your photos

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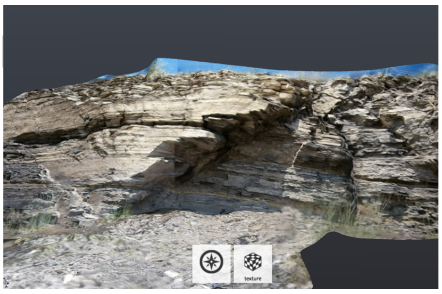
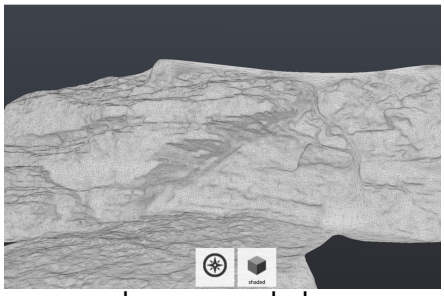
Drones can take photos that can be analyzed later. By planning ahead to have enough overlap between photos, you take those individual photos and make a 3-dimensional image!

In this activity, you guide the students to identify an outcrop or landform to study later or over repeat visits. They go through the process to plan, conduct, and analyze an investigation to help answer their science question.





Their Challenge: Design and conduct an experiment to take enough photos to make a 3-dimensional image of an outcrop or landform, then analyze the image and interpret the resulting 3-d image.

For instance they might wish to study a hillside that has been changed from previous forest fire. How is the hillside starting to shift after rainstorms or snows? Monitoring an area over many months can lead to discoveries about how the erosional processes happen and also provide homeowners, park rangers, planners, and others valuable information to take action to stabilize areas to prevent landslides.

Lesson plan

Topics: Earth processes, Mathematics, Engineering and technology, planning an investigation, conducting an investigation as a team, interpreting data, identifying patterns, constructing explanations

Grade Levels: 6 – 14

Teaching Time: 2-3 hours (3 class periods or more). One session to develop an investigation plan, one to collect the data, and a final session to generate the models and analyze it.

Objectives

Students will be able to:

- Design and implement a field experiment to effectively collect data for use in the generation of 3-dimensional computer models.
- Investigate how camera angle impacts photographs and how shapes appear within the photographs.
- Investigate a science question that uses a 3-dimensional model to inform their analysis.
- Develop and interpret a 3-dimensional model of a land surface from overlapping photographs.
- Identify additional earth science projects where a drone-mounted camera is useful.

Lesson Overview & Organization: This activity consists of 7 principal parts:

1. Write a draft question: What are you trying to discover by making the 3-dimensional image?

2. Make a plan
    a. Sketch a map showing planned route
    b. Sketch a drawing of where the photos will be taken
    c. Plan for Safety
3. Field work: Carry out the investigation and collect data
4. Create the 3d model(s)
5. Analyze & interpret the model(s)
6. Assessment: Students describe what have they learned from data and the project.

Credits

This activity was developed by Shelley Olds, UNAVCO with Earth Science Information Partners (ESIP).

Lesson Format

Hands-on activity (collecting data with the drone) and computer-based activity (creating 3d model).

Education Standards Addressed

Next Generation Science Standards

Science and Engineering Practices

- asking questions (for science) and defining problems (for engineering)
- developing and using models
- planning and carrying out investigations
- analyzing and interpreting data
- using mathematics and computational thinking
- obtaining, evaluating, and communicating information

Crosscutting Concepts

- patterns
- scale, proportion, and quantity

Disciplinary Core Ideas

- MS-PS4.B: Electromagnetic Radiation
- MS-PS4.C: Information Technologies and Instrumentation
- MS-ETS1.A: Defining and Delimiting Engineering Problems
- MS-ETS1.B: Developing Possible Solutions
- MS-ETS1.C: Optimizing the Design Solution
- HS-PS4.B: Electromagnetic Radiation
- HS-PS4.C: Information Technologies and Instrumentation
- HS-ETS1.A: Defining and Delimiting Engineering Problems
- HS-ETS1.B: Developing Possible Solutions
- HS-ETS1.C: Optimizing the Design Solution

Materials:

- Drone with a camera or a long pole to attach a camera
- Extra batteries
- One-meter circle or square laid on the ground (cloth or tarp) and long tape measure
- Software that will make a 3D image from photos:
    - Autodesk Recap: https://recap360.autodesk.com/
    - SketchFab: show off your models! https://sketchfab.com/
    - App to scan using an iphone: Trnio: a smartphone 3d scanning application http://www.trnio.com/
    - App to scan using an Android device: Scann3d: http://scann3d.smartmobilevision.com/
- Provide students with a link to worksheet page or supply them with printed copies of that document

Background Information

The process of taking many overlapping photos to construct a three-dimensional model is often called structure from motion (SfM). This photogrammetric technique has many research applications in geodesy, geomorphology, structural geology, and other subfields of geology. Learn more about this technique in the Geodesy Tools for Societal Issues unit: Introduction to SfM.

Instructions for teachers

The Challenge: Students will design and conduct an experiment to take enough photos to make a 3-dimensional image of an outcrop or landform.

Taking photos from multiple viewpoints can yield better 3d models, so using a drone with a camera onboard, from the ground, a balloon and/or from a tall pole might be useful for the study.

Example - Post-fire hillsides: An investigation to monitor a hillside or road cut for pre-landslide movements such as slumping after a wildfire has removed all of the vegetation.

Have students write a draft question you want to answer: What are you trying to discover by making the 3-dimensional image?

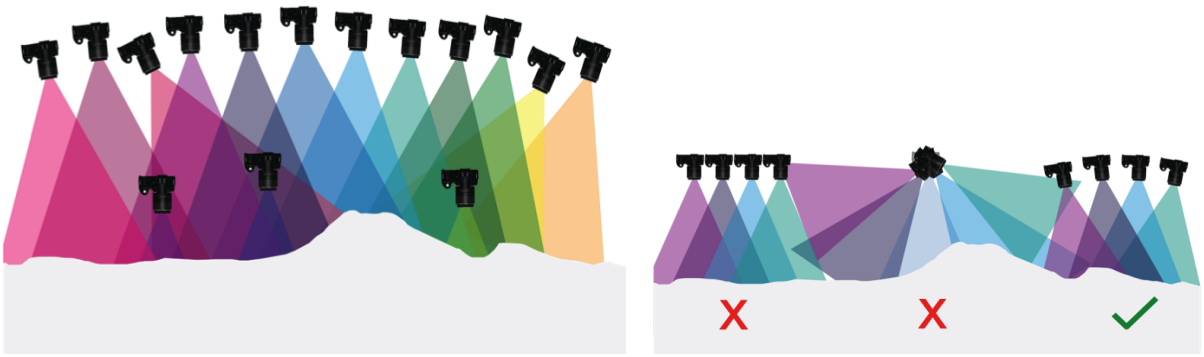
Have students make a plan

- To develop their plan, students need to know the size of the area they want to photograph and field of view of the camera(s).
- Have students discuss who is needed for the team. Who will be the pilot? The photographer? The spotter? If students use a camera that sends its image to a screen or phone, they should designate a photographer to take the photos.
- Have students discuss hazards that need to be avoided.

Tell students to sketch a map showing planned route for your drone to fly and from which directions. Show where the pilot, photographer, and spotters will stand. Think about the order & from angles will you take the photos.

Ask students to sketch a drawing of where the photos will be taken. How far from the outcrop will the drone need to fly and get enough detail for your project? How many photos will you need to take to have 70% overlap? Where: how high, from how far away, how many? When during the day, during the year, after an event? Each photo should overlap the previous photo by 60% - 80%. If multiple rows of photos are taken, remember to overlap the rows by 60% - 80%. (left image). Less effective scans result from only taking photos straight on or in a divergent pattern (as in taking the photos while standing in one spot and turning the camera) (right image).

If possible, do a test run to take and process a portion of your outrop – a small-scale scan can provide hands-on experience for refining your procedures.



(Image credit: Kate Shervais, UNAVCO)

Tell students to think about:

- How does the angle of camera on the drone impact the photos? Are circles still circles in the photograph?
- What environmental or drone-based variables could interfere with your photographs?
- What other information should be in your sketch?
- How you will measure the size of objects and the height of your drone? (Hint: cut a tarp into a circle or square, one-meter across – other methods?)

Discuss safety considerations**:** Is it safe to fly a drone? If the study area is near the road, are you and your team safely off the road?

Field work: Take the photos and measurements

Have students carry out your investigation and collect data:

1. They should add information about photos in a table to record data about each session and flight and to take measurements to calculate the object and heights.
2. Have students take a few photos of the full area being investigated – later show the outlines of the individual images from each flight to calculate area and overlap.
3. Have students make a table similar to the one shown below to record their data.
4. After the investigation, have students show locations of photos on map & site photo. What new questions did they think of while conducting the investigation?

Flight Number:	Test circle	1	2	3	4	5
Name of pilot, photographer, spotter(s)						
Date + Beginning & ending time of flight						
Filenames of photos (range)						
Height above ground, distance from the outcrop & area covered of each photo. Direction of image collection (panorama, walk, spin - around, zig-zag, etc)						
General description of images*						
After each flight, sketch the path on your map.						

* Consider describing: Are there trees, bushes, grasses in front of the outcrop? Lighting – cloudy/sunny? How far do roots go into the rock? How is the rock where there are roots different than other areas? Color, consistency, staining, etc.

Have students create the 3d model(s)

Using a online software such as Autodesk Recap to stitch the photos together to make a 3D image. Two smart device applications are Trnio (Apple ios) and Scann3d (Android). SketchFab is an online site for showing off your models!
http://scann3d.smartmobilevision.com/

Recap is currently free and allows 50 photos in a model. A single 'row' of photos with lots of overlap (think zig-zag up and down) works well for this application. An alternative is to take the photos with the drone (or other camera) then import them into a 3d model application on a smart device, such as Trnio or Scann3D. There are many applications that will create 3D models, such as Agisoft, that are not free.

Ask students analyze & interpret the model(s)

Have students analyze the model for answering their question and for how the model turned out: How do the models contribute to answering your questions? What parts of the 3-d model look 'better' than other parts? What can you learn by reviewing the locations that photos were captured vs the end model?

Have students measure the objects in some of their photos. Are circles actually circles? This can provide information about the distortion of the objects in the images and models. Ask students to generate statistics from their data.

Assessment: Students describe what have they learned from data and the project
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- Tell students to compile flight log, hypothesis, images, data chart, conclusion and any additional project pictures and results into a short report (or PowerPoint) for a classroom presentation or science fair exhibit.
- Ask students how they would have changed their investigation designs. What modifications, sensors, and/or instruments would have helped with their projects? Suggest that they take a look at the engineering design loop for ideas.
- Tell students to brainstorm additional projects they can do with the camera on their drone. What other 3D projects could they do? How could printing the 3D image help with their analysis, communication, etc.?