OUT TO LUNCH: USING RECREATIONAL UAVS (DRONES) FOR STEM ACTIVITIES AND SCIENCE FAIR PROJECTS

Education Committee

Federation of Earth Science Information Partners

Presenter: Shelley Olds, UNAVCO

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

Recreational drones

- ❑ weigh less than a half pound
- ❑ do **<u>not</u>** 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 **UAV**s

Unmanned Aircraft Systems or **UAS**s

Quadcopters / Quadrocopters

Multi-rotors / Helicopters

Fixed-wing drones

Aerial robotics

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

Got a drone?

Try this...

Learning Activities and Science Fair Project Suggestions for You and Your Recreational Drone

Maneuvering through a fast-paced video game takes skills—piloting an unmanned aerial vehicle (a drone) in the real world can present an even bigger challenge. Flying a recreational drone pits you against the law of gravity as well as environmental conditions. When you attempt to accomplish some goal with your drone, you use your joystick skills as well as some science and engineering concepts.

Check out the activities in this guide for ideas about what you might learn with your drone. Team up with some helpers or other drone pilots to compete or collaborate on one or more activities. If you set out to learn something, and document your procedures, you could fly your way to a winning science fair project.

Note that this guide is not designed to teach you how to fly your drone... We assume that you've already learned the skills you need to safely pilot your drone, and you're ready to apply those skills in new ways.

List of Activities

- What payload can my drone carry?
- How fast can my drone fly?
- How high can my drone fly?
- A 3d view from a drone
- Science Project and Science Fair Template
- Comparing images from satellites and drones
- Collecting data with drones
- UAV Challenge: Aerial Survey of a Disaster Area
- *Supplemental materials*

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?

Sample Data Table

	UAV only	UAV + Payload #1	UAV + Payload #2
Mass			
Ability to launch (good, fair, poor, fail)			
Ability to maneuver (good, fair, poor, fail)			
Payload mass			

FLIGHT SESSION DATA SCIENCE DATA

Drone Flying Session

29 Jan 2016

Weather: Sunny + calm

Back patio at
8527 E Mallory St
Mesa AZ

Flat patio + yard, cactus beyond.

Drone Model: Propel Altitude 2.0
Batteries A + B, used interchangeabl[y]

Pilot: B.Bundy
Recorder: LDahlman

Activity: What Payload can my UAV C[arry]

Notes:

Taking off from a perch atop a wide plastic cup helped facilitate take-off. Otherwise, the drone wasn't level sitting atop the attached weights.

Drone Activity Testing 29 Jan 2016

L Dahlman
B Bundy

What ~~mass of~~ payload mass can my drone carry?

	Mass(g)	Ability to Launch (Quick / Slow / Struggle / Fail)	Ability to Maneuver (Good / Fair / Poor / Fail)
Drone + battery	150	Quick	Good
Payload 1 (~~Drone +~~) ~~Total weight~~	50 ~~200~~	Quick	Good
Payload 2 ~~Total weight~~	100 ~~250~~	Quick	No results
Payload 3 ~~Total wt~~	150 ~~300~~	Fail	~~No~~ Fail
Payload 4	125	Fail	Fail
Payload	112½	Struggle	Poor

How fast can my drone fly?

An afterschool group decided they wanted to make a snapshot of a specific tree on their campus every day. In order to figure out how much time it would take to fly out to the tree, get the picture, and fly back each day, they needed an estimate of the drone's average forward speed.

The Challenge:
Design and conduct an experiment to find a practical maximum speed your UAV can fly.

Suggested Materials:

- Sports field with marked distances
- Stopwatches
- Several people to serve as timers / spotters

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Distance					
Time					
Average Speed					

How high can my drone fly?

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.

DRAFT for review Please direct feedback and/or questions to education@esipfed.org

	Example	Trial 1	Trial 2	Trial 3
Distance from pilot to observer	30 feet			
Observed angle to drone	43°			
Observed angle to the location directly below the drone	10°			
Calculation (Tan(∠a) x distance from pilot to observer) + (Tan(∠b) x distance from pilot to observer) = Drone height above ground	(Tan (33) x 30 feet) + (Tan(12) x 30 feet) = (19.5 feet) + (5.3 feet) = 24.8 feet			
Drone Height	24.8 feet			

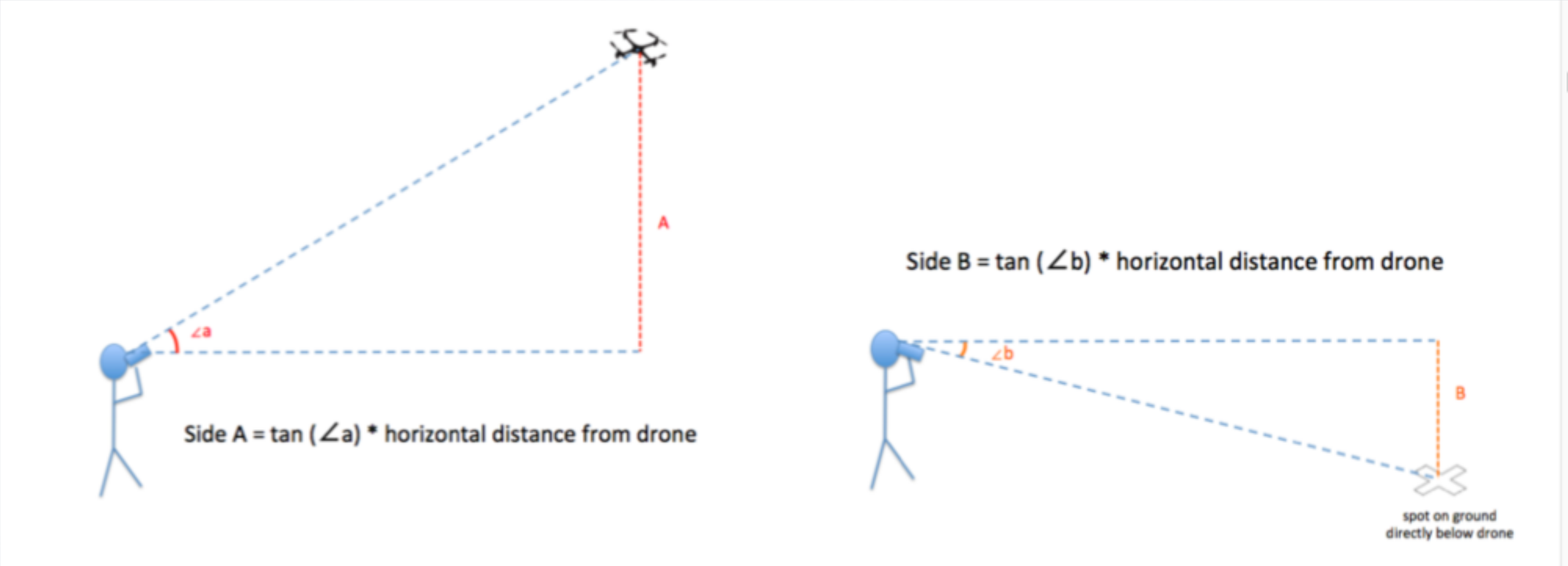
Think it through:

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?



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Create a 3D view from a drone

The Challenge:

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

Ex: a rock outcrop or a sculpture

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A 3d view from a drone

When walking on a hike or around the schoolyard, sometimes you see something that is high up on a rock outcrop or a wall that catches your interest. Drones can fly up and take photos that you can anlyze later. By planning ahead to have enough overlap between photos, you take take those individial photos and make a 3-dimensional image!

The Challenge:
Design and conduct an experiment to take enough photos 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 questions & define a problem: Pick a question that you want to try answering with your drone.

What can we learn about the rocks where plants are growing on a rock outcrop?

2. Develop & use models: Draw a diagram that shows what you think the rocks and plant roots look like.

3. Create a draft title based on your project question:

Rock, paper, vegetation: An investigation using drones to photograph plant roots breaking rocks

4a. Plan your investigation: Think it through: What are you steps? What will you do to collect the information you need?

Suggested materials:

1) Drone with a camera
2) One-meter circle or square laid on the ground (cloth or tarp)
3) Software that will make a 3D image from photos:
   a. Photosynth: *Capture your world in 3D:* https://photosynth.net - make the 3d image
   b. Autodesk 123D: http://www.123dapp.com/catch
   c. SynthExport: https://synthexport.codeplex.com/ - export tool

Questions to consider as you plan:
What other materials would be useful? What do you plan to photograph?

What order & from what angles will you take the photos? Where: how high, from how far away, how many, how much overlap (>70% if making 3-dimension image)? When during the day, during the year, after an event?

What other data is needed? 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?

Does the sample data table in step 5 include all the information I need? Who do I need on my team? Who will be the pilot? The photographer? The spotter?

4b. Sketch a map showing planned route for your drone to fly and from which directions. If you are taking photos, where will the photos be taken? Where will the pilot, photographer, and spotters stand?

What other information should be in your sketch? 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? What hazards are there to be avoided?

4c. Use Math / Computational Thinking: 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?)

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5. Fly your drone and collect your data. (Carry out your investigation): Add information about your photos in a table. What new questions did you think of while conducting your investigation? Record data about each session and flight.

Consider making a table similar to this for your data:

Flight 1: Location identification numbers for map	Name of pilot, photographer, spotters	Range of photo numbers	Date & Time Range	Height above ground, Distance from the outcrop & Area covered of each photo. Direction of image collection (Panorama, Walk, Spin, Wall)	Description of image (Are there trees, bushes, grasses at the top of the outcrop? How far do the roots go into the rock? How is the rock where there are roots different than other areas? Color, consistency, staining, etc.)
Test circle	Pilot: Photographer: Spotters:				

6a. Analyze & Interpret Data: Use your data to answer the question you asked. Organize the data – How do they contribute to answering your questions?

Using software such as Photosynth or Autodesk 123D, stich the photos together to make a 3D image or panorama.

6b. Use Math / Computational Thinking during your analysis:
Measure the objects in your photos - are circles actually circles? How do the sizes of objects in photos change with distance and height of the drone? Generate statistics from your data. What patterns do you see in the rocks and/or roots? How far or how large an area of the outcrop has plant growth in it?

7. Construct Explanations & Design Solutions: What have you learned from data that help you answer your project questions? How would you have changed your investigation design? Consider adding the answers from the questions to consider in step 4.

What modifications, sensors, and/or instruments would have helped with your project? Take a look at the engineering design loop for ideas.

8. Engage in argument from evidence: What questions might others ask you? How would you respond and how would you use your data and analyses as supporting evidence for your discussion?

9a. Present your results: Communicate: Make a Science Fair Display of your project and results

Compile flight log, hypothesis, images, data chart, conclusion and any additional project pictures and results into a short report (or power point) for a classroom presentation or science fair exhibit.

9b. Communicate & Evaluate: What would you tell your community leaders? Go online – what information would add to your project? What other ways could you use this information? What other data would be useful to evaluate if drones are useful & successful for these types of investigations?

Brainstorm additional projects you can do with the camera on your drone; what other 3D projects could you do; how could printing the 3D image help with your analysis, communication etc.

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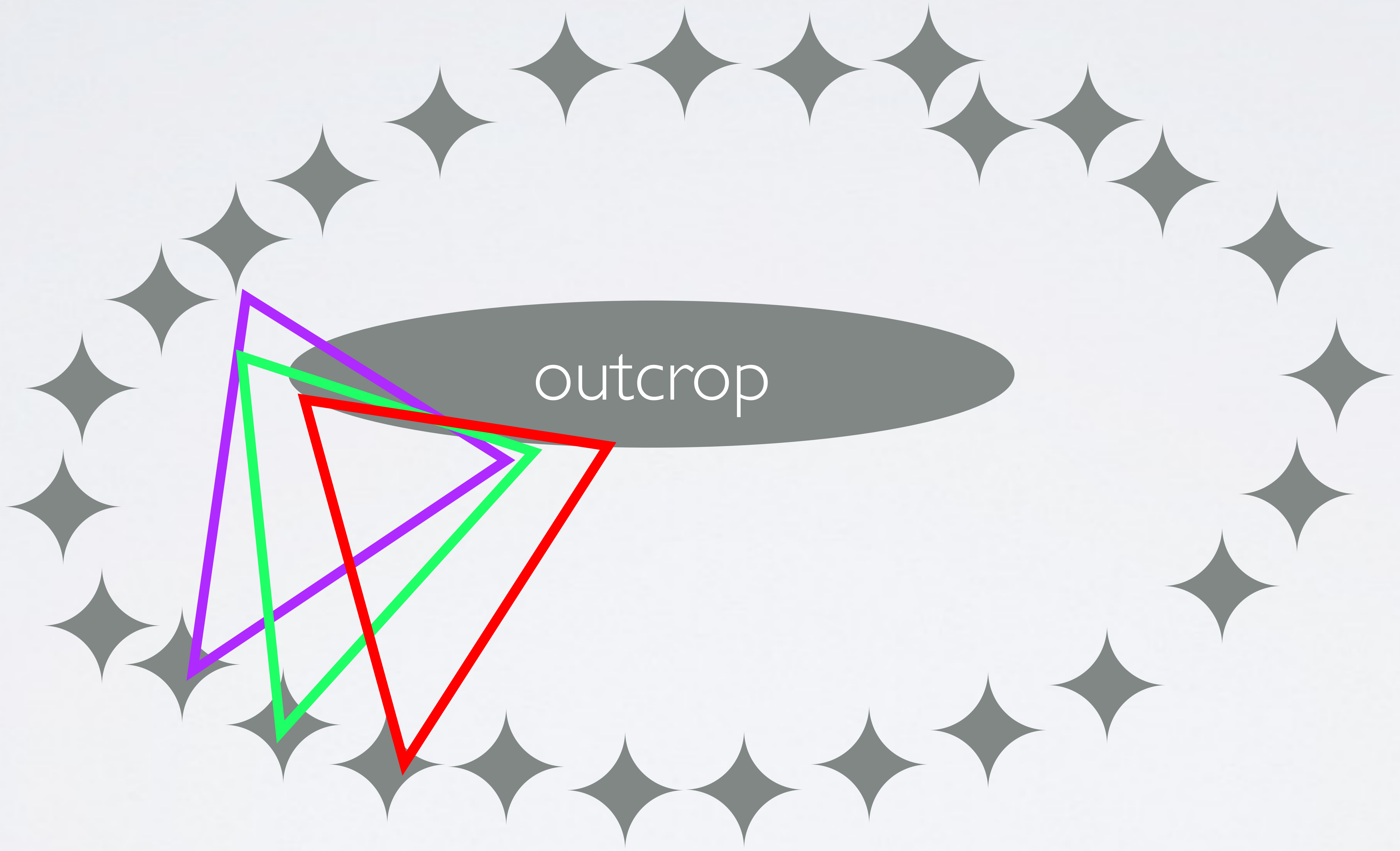
PLANNING THE OVERLAP OF PHOTOS



Science Fair Template

The Science Project & Science Fair Template Use these science & engineering practices to guide you through an investigation or project.

1. Ask questions & define a problem: Pick a question that you want to try answering with your drone

Your Name & Team members

2. Develop & use models: Draw a diagram that shows what you think you will find.

3. Create a draft project title based on your question:

4a. Plan your investigation: What are you steps? What will you do to collect the information you need?

4b. Sketch a map showing planned route for your drone to fly and from which directions. If you are taking photos, where will the photos be taken?

4c. Use Math / Computational Thinking: 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?)

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5. Carry out your investigation: Add information about your data in a table. What new questions did you think of while conducting your investigation? Record data about each session and flight. Use your data to answer the question you asked.

6a. Analyze & Interpret Data: Organize the data – How do they contribute to answering your questions?

6b. Use Math / Computational Thinking during your analysis: Measure the objects in your photos - are circles actually circles? How do the sizes of objects in photos change? Generate statistics from your data. What patterns do you see?

7. Construct Explanations & Design Solutions: What have you learned from data that help you answer y… questions? How would you have changed your investigation design?

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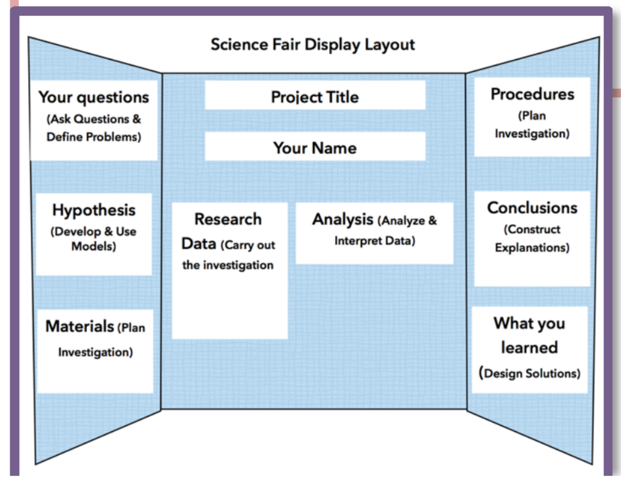
8. Engage in argument from evidence: What questions might others ask you? How would you respond and how would you use your data and analyses as supporting evidence for your discussion?

9b. Communicate & Evaluate: What would you tell your community leaders?

What other data would be useful to evaluate if drones are useful & successful for these types of investigations?

9a. Communicate: Make a Science Fair Display of your project and results

Go online – what information would add to your project? What other ways could you use this information?



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Comparing Images from Drones with Satellite Images

Comparing images from Drones with Satellite images

Objective: Explore the basic concepts of remote sensing by comparing data collected by instruments on polar orbiting satellites with pictures and videos collected via cameras on recreational drones.

Materials:

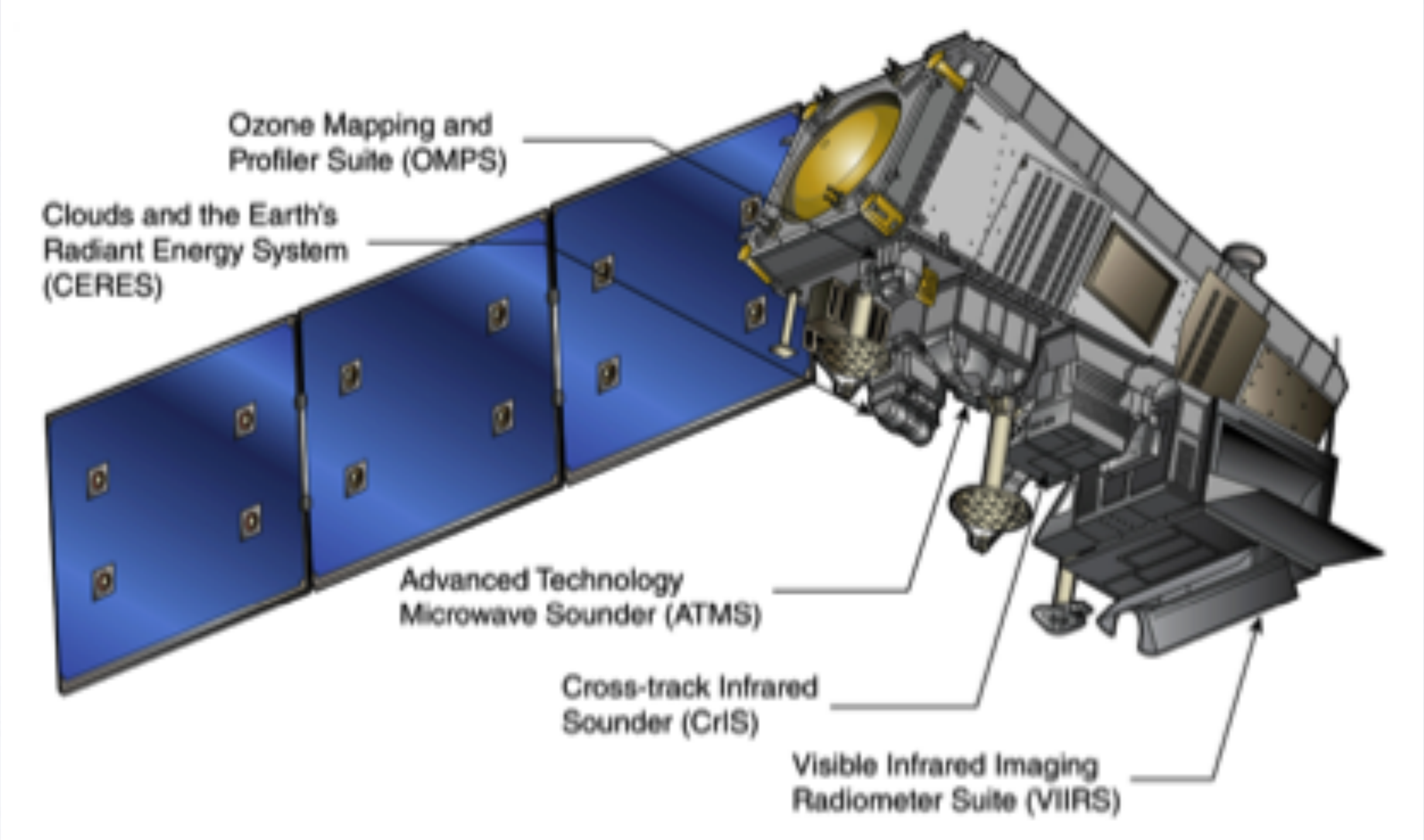
1) Satellite Image of your location
    a. SatCam (free citizen science app for iOS devices) http://satcam.ssec.wisc.edu/
    b. MODIS Today (free images via any web browser) http://ge.ssec.wisc.edu/modis-today/
2) UAV with camera

Steps:

1) Make a hypothesis about this data comparison, for example:
“The satellite image will cover a greater area than our drone” (YES, of course, but you get the idea)
2) Acquire a satellite image on the same day you plan to fly your drone. Identify as many features as possible (clouds, bodies of water, vegetation types, cities or towns etc...)
3) Conduct a drone flight and collect camera pictures. Identify as many features as possible.
4) Organize your data, here is an example of a table you could create:

Date	**Satellite Image**	**UAV Photo**
Data Source & time (temporal resolution)		
Area Covered (include units)		
Smallest feature (spatial resolution)		
Largest feature (scale)		

5) Make a conclusion based on your data
6) Brainstorm additional projects you can do comparing drone data with satellite images, for example: green-up or green-down, identifying ice on near-by lakes, investigating fall foliage, etc...



Collecting [Sensor] Data with Drones

Collecting data with drones

Objective

To give students experience with how drones can be valuable for collecting scientific data, thereby support their inquiry skills as well as their knowledge of drones, knowledge of sensing instruments, and experience flying drones and collecting data from them.

Course Name: Earth Science

Grade Level(s): 6-12

Lesson Plan:
Collecting atmospheric data with recreational drones

Goals

Students will make predictions, justify their predictions, design a pred
that involves flying a drone with a sensor. Then they will analyze thei
predictions were correct and suggest a follow-up study

Estimated duration: Three 45-minute class periods

Measurable objectives

1. Salient prediction and justification
2. Feasible design of investigation
3. Successful drone flight and data collection
4. Appropriate analysis of the data results
5. Design of follow-up study that follows logically from the res

Instructional sequence

Period 1: Prediction Justifications, and Investigation Planning

Period 2: At minimum, one class period, though this phase cou
depending on the scope of the investigation

Period 3: Data analysis and follow-up suggestion

Materials: Sensor, plus drone with enough lift to carry the sensor pay

Assessment : Rubric-based scoring on the measurable outcomes.

Activity: Collecting data

Introduction

Did you ever wonder how much air changes with altitude? Does it always get colder or moister? Does the pressure always decrease? And, how much do these conditions change? Do the changes vary with the weather, or time of day, or season, with what's on the surface, or with the elevation? Drones are great vehicles for collecting data to study these things.

Directions

1. Make a prediction. For example, "If I launch a drone on a flat grassy surface 20 feet above sea level at noon on the first day of every month for a whole year, I predict that there will always be a decrease in temperature going up 200 feet, but sometimes there will be a bigger difference between the surface temperature and the temperature at 200 feet than at other times.

2. Explain your reasoning behind the prediction. For example, "I predict this because I know that air is thinner the higher you go and so is its retention of radiated heat at the surface."

3. Choose a sensor. Make sure the sensor is designed to be capable of having its data uploaded to a computing device for analysis.

4. Use Velcro or a well tied string to attach the sensor to the drone.

5. Decide how high you want to fly the drone.

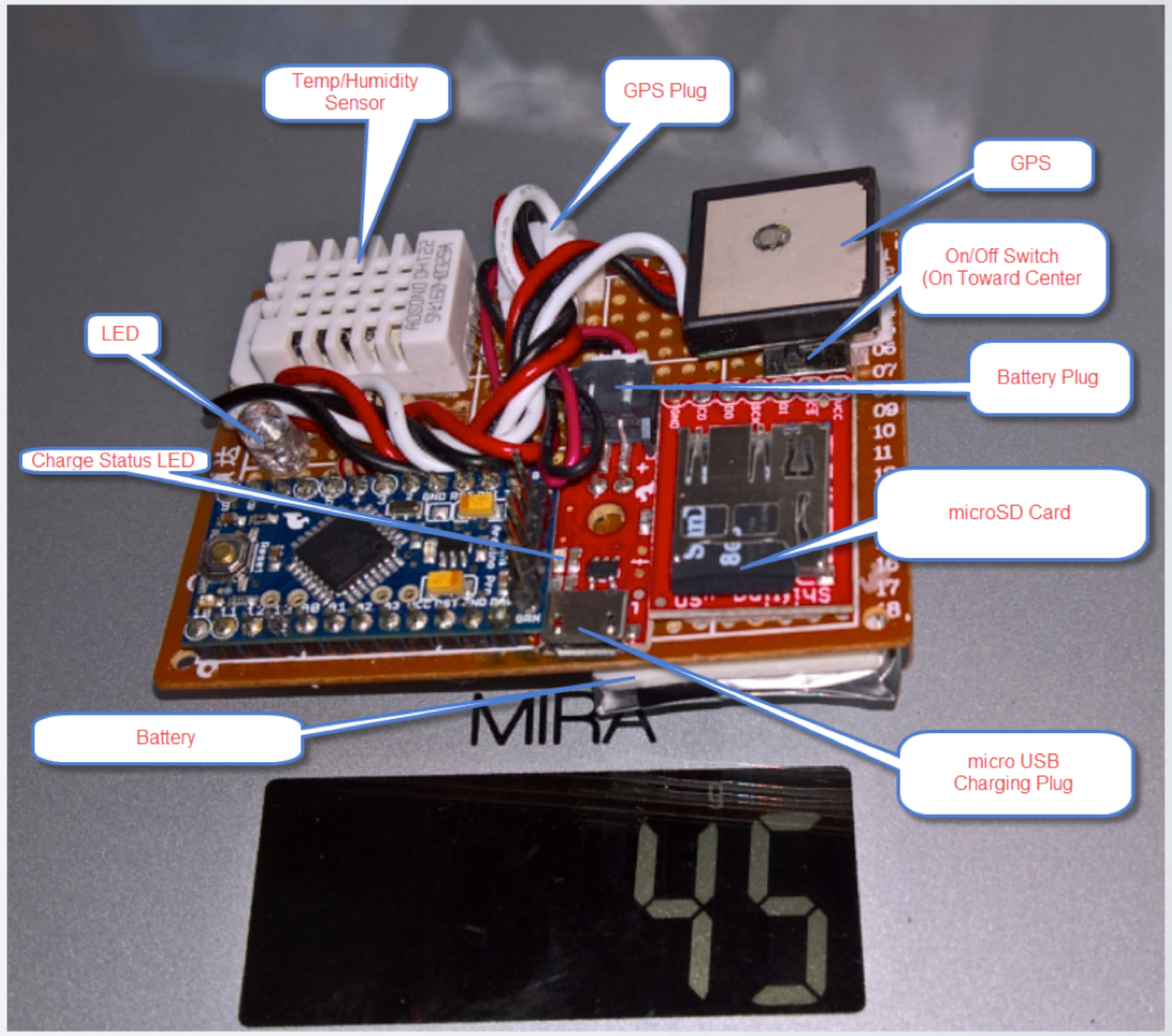
6. Make a table to record your data. Make one column for elevation and another for data readings from the sensor.

7. Fly the drone, and note the data readings at equal intervals of change in elevation. For example, if you are flying your drone up to 200 feet, you could take a reading at a height slightly above ground level, then at 50 feet, 100 feet, 150 feet, and 200 feet.

8. Once you have the data, determine if your prediction is correct and try to render a scientific explanation for the results.

9. Present your data and explanation.

10. Suggest what would be a good follow up study with the drone.

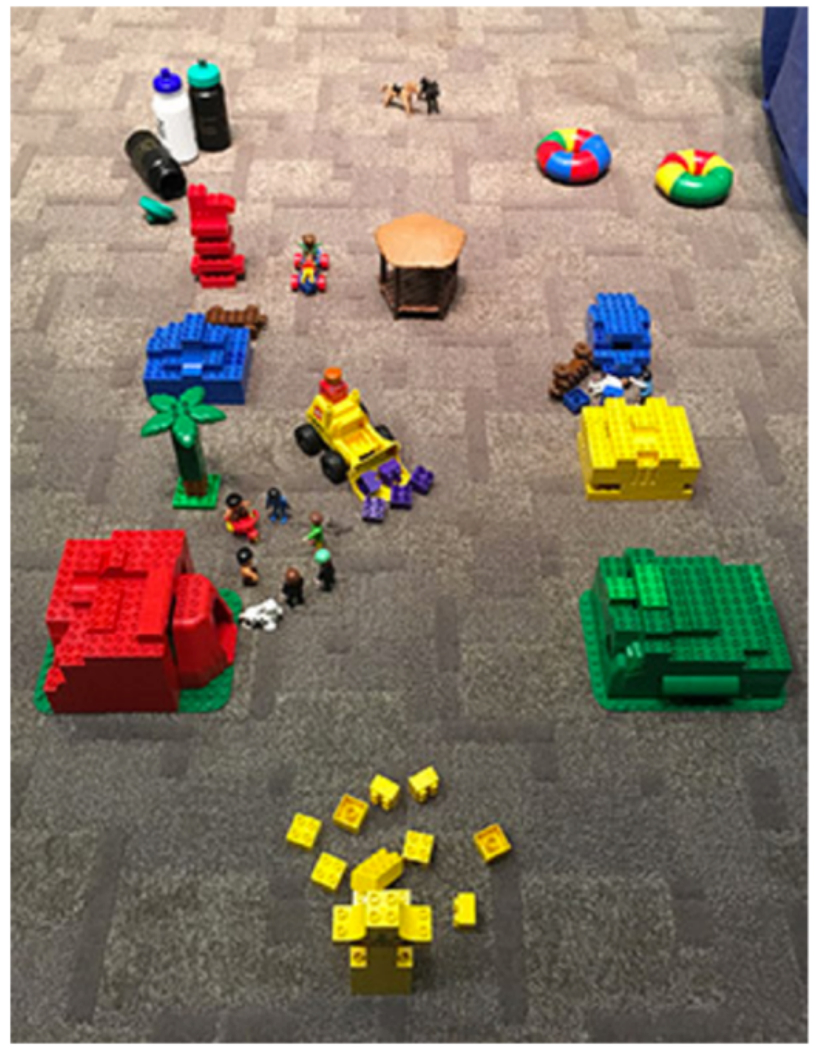


UAV Challenge: Aerial Survey of a Disaster Area

Print UAV Challenge: Aerial Survey of a Disaster Area

Overview | Instructions | Background & Extensions

Introduction



Students will fly their UAVs (Unmanned Aerial Vehicles or "drones") over a scale-model town that has been struck with a disaster, surveying the damage via a camera on the UAV.

This activity can serve as a culminating activity in a series of UAV activities (see links below) that build upon each other. This activity can serve as a performance assessment for the entire sequence of activities, since the challenge presented in this activity incorporates skills and knowledge gained from all the other activities in this series.

The **"UAV Challenge: Aerial Survey of a Disaster Area activity - demonstration for teachers" video** provides an overview of this activity, including activity setup and sample video footage shot from a UAV's camera.

We recommend that students complete the **Learn to Fly! UAV Flight School**, **Learn to Fly! UAV First Flight** and **Learn to Fly! Aerial Maneuvers with a UAV** activities as prerequisites to this activity.

You might also want to have your students experience the **UAV Performance Test: Carry a Payload** activity in preparation for this activity. In the Carry a Payload activity, students determine the maximum weight that their UAVs can lift. In that activity students become familiar with the way additional weight affects the flight performance of their UAV. That familiarity could be handy in this activity, in which the UAV carries the extra weight of a camera.

You might also wish to have your students complete the **UAV Performance Test: Battery Lifetime** activity before trying this challenge. That activity will help them estimate how long their UAV can stay airborne, which will help them plan their mission strategy in this challenge.

Credits

This activity was created by Randy Russell and John Ristvey of the UCAR Center for Science

UAV Challenge: Aerial Survey of a Disaster Area

Print UAV Challenge: Aerial Survey of a Disaster Area

Overview | Instructions | Background & Extensions

Materials

For each Student:

- safety goggles

For each Group:

- photo(s) of what the simulated town looked like before the disaster
- items (tape, rubber bands, pipe cleaners, etc.) for students to use to attach a camera to their UAV in an orientation that allows it to capture images of objects directly beneath the UAV
- one or more UAV ("drone") with a camera and the controller used to fly the UAV
  - **Note:** we used the SYMA X5HW-I. Some of the instructions and images are specific to this particular model, but most aspects of this activity can be done equally well with other UAV models.
- smartphone or tablet computer with software app for displaying the images and video from the UAV's camera
  - **Note:** the SYMA brand UAV that we used while developing this activity includes a software app called SYMA FPV that runs on smartphones or tablets. The app allows you to connect with the UAV's camera during flight, watching the live video feed from the phone or tablet. It also allows you to record the video feed or to take still photos whenever you choose. You will need to download and install the SYMA FPV software onto the smartphone(s) and/or cameras you plan to use with this activity. If you are using a different UAV model, consult your user's guide for information on viewing and recording video and photos with your UAV model.
- extra batteries for the UAV
- stopwatch (optional)

For the Class:

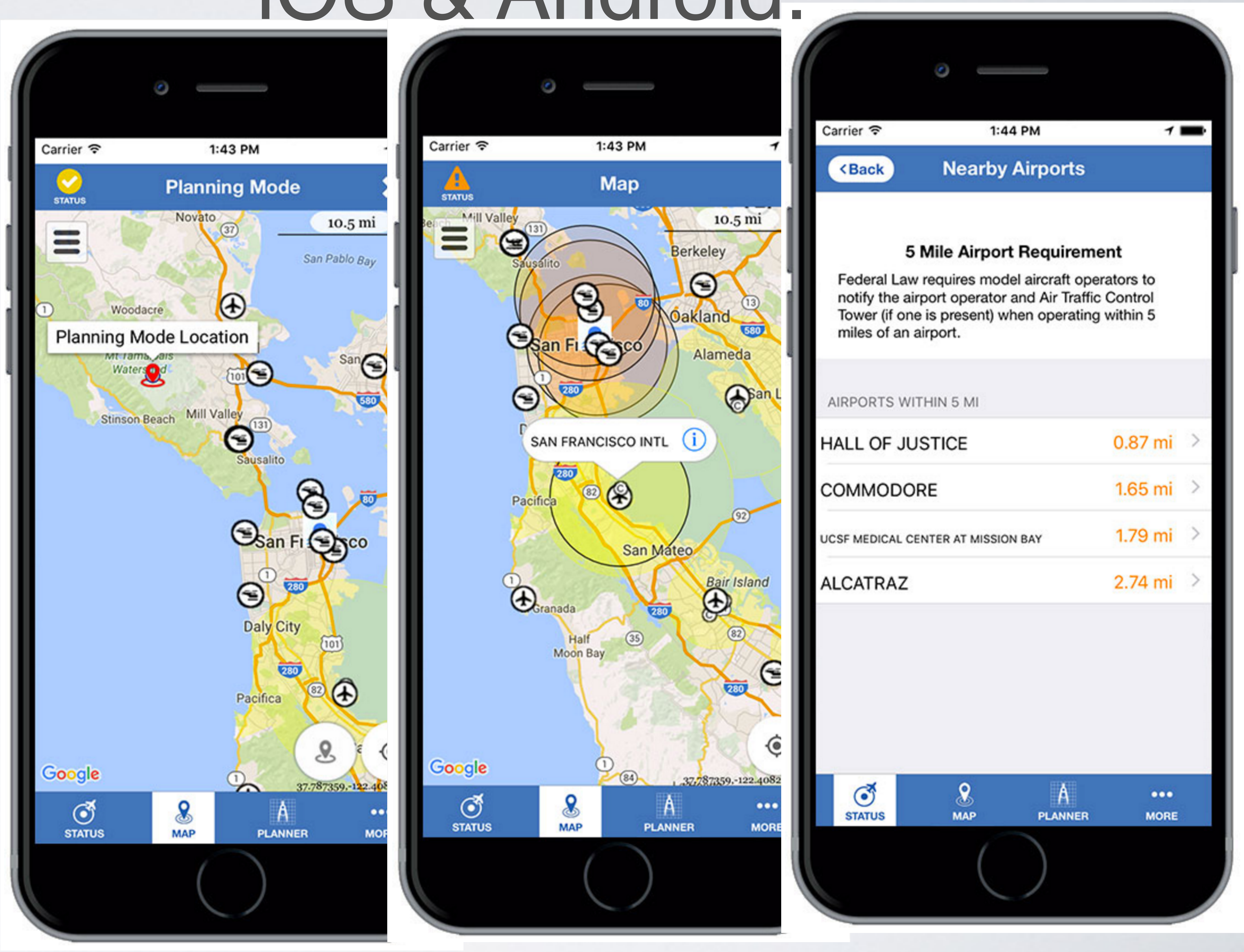
- an open space in which to fly. We recommend flying indoors in a large open space like a gymnasium. Minimally, an area 20x30 feet with a ceiling height of 15 feet should suffice.
- materials for building the simulated, scale-model town. (See Bulding the Town, below.) Items such as toy cars and buildings, Duplo™ and/or Lego™ blocks, small dolls and figurines, water bottles and similar items work well. Avoid items that are too lightweight - the "wind" from the UAV's propellers can blow those around - and items that could break if the UAV lands or crashes onto them.
- materials for building a barrier that blocks the students view of the simulated town; such as a waist-high "mountain range" made by draping a plastic tarp over a few chairs

Supplemental materials

- Know Before You Fly
- Science / Flight Team & Roles
- The Process of Science & Engineering Practices and Engineering Design Working Together
- Pre-flight checklist: before every flight
- Flight data sheet

Know Before You Fly

Free for iOS & Android.



Check for specific restrictions in parks, near sensitive facilities, and places where you might disturb wildlife.

knowbeforeyourfly.org

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

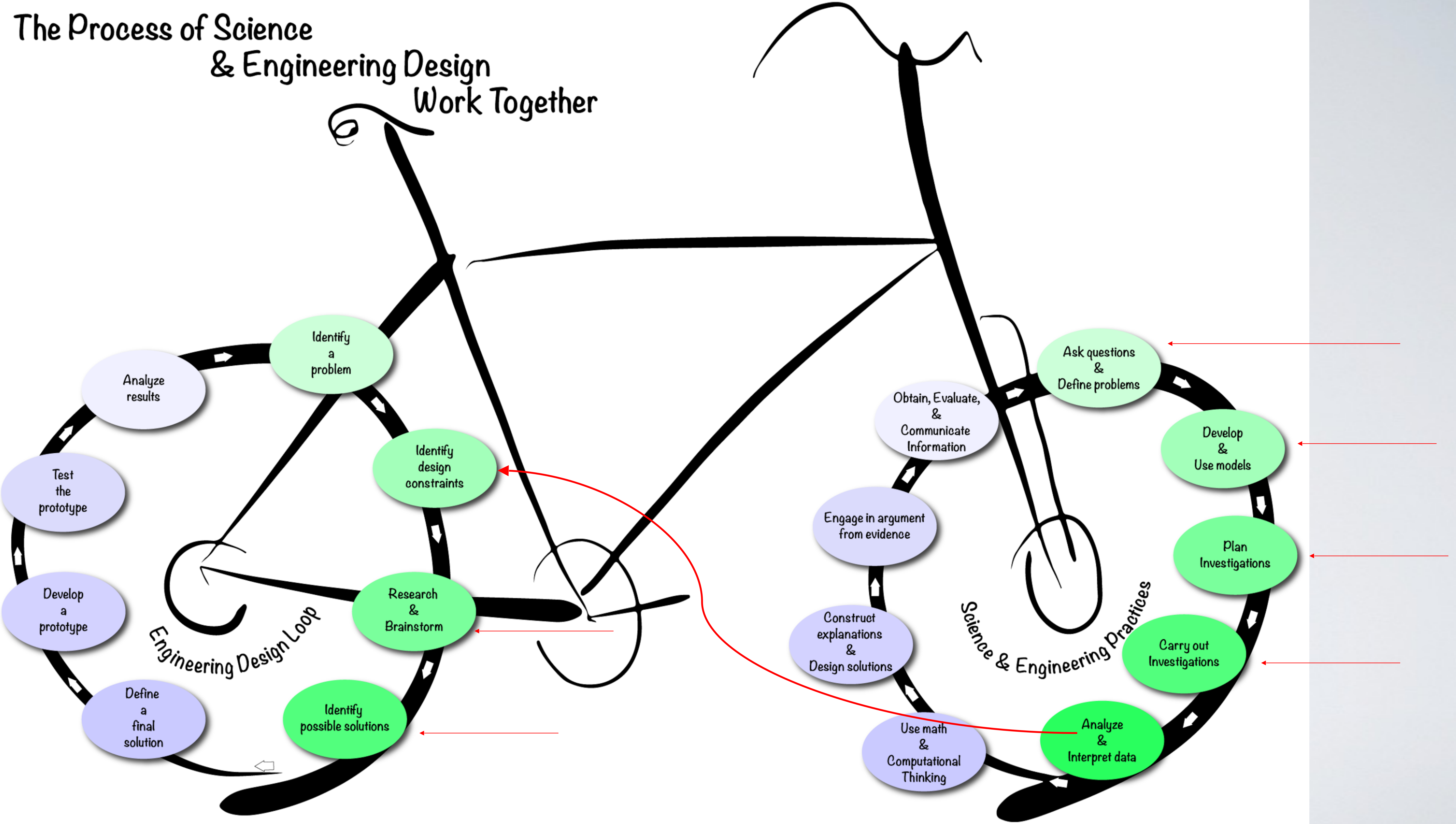
In-flight

- Flies the drone - follows investigation instructions from Data Recorder
- Keeps drone in site & lands safely

Post-flight

- Turns off drone, etc.

The Process of Science & Engineering Design Work Together



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**

FLIGHT DATA SHEET

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:


Trent
Yvonne

Thank you!

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