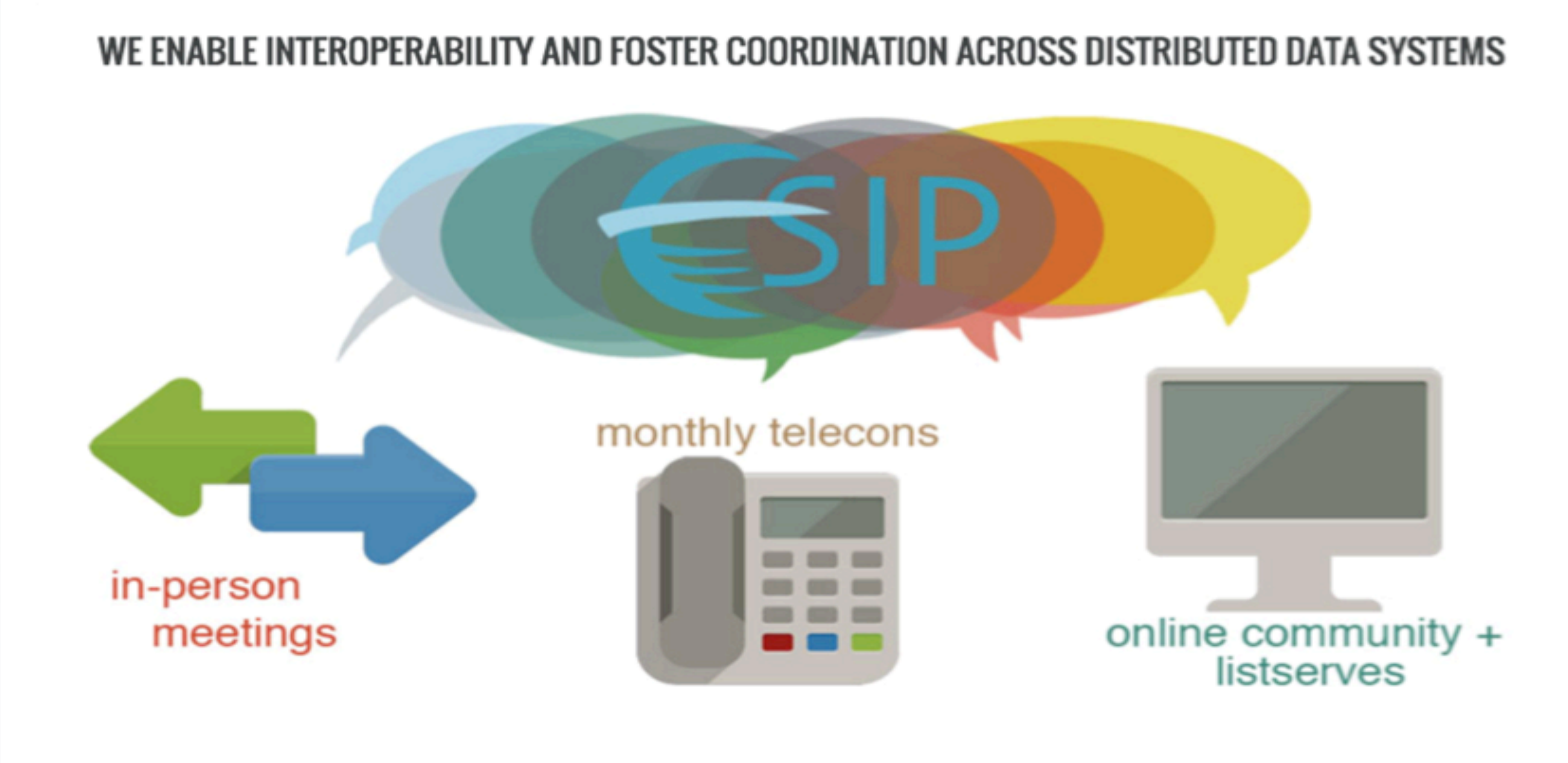
USING RECREATIONAL UAVS (DRONES) FOR STEM ACTIVITIES AND SCIENCE FAIR PROJECTS

Education Committee
Federation of Earth Science Information Partners

Presenter: Shelley Olds, UNAVCO

ABOUT ESIP - THE FEDERATION FOR EARTH SCIENCE INFORMATION PARTNERS



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

CIMSS Cooperative Institute for Meteorological Satellite Studies

Earth Exploration Toolbook
Step-by-Step Guides for Investigating Earth System Data

Education & Learning »
SRI International

U.S. Climate Resilience Toolkit

UNAVCO

picture post
Digital Earth Watch DEW

Windows to the Universe

NOAA National Oceanic and Atmospheric Administration U.S. Department of Commerce

NASA

UCAR University Corporation for Atmospheric Research

UAVS 4 STEM: TWO WEBINARS AND WORKSHOPS

UNAVCO

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.

NSTA Regional Workshops: Denver STEM Forum, Minneapolis, MN; Portland, OR; Columbus, OH

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 **UAV**s

Unmanned Aircraft Systems or **UAS**s

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

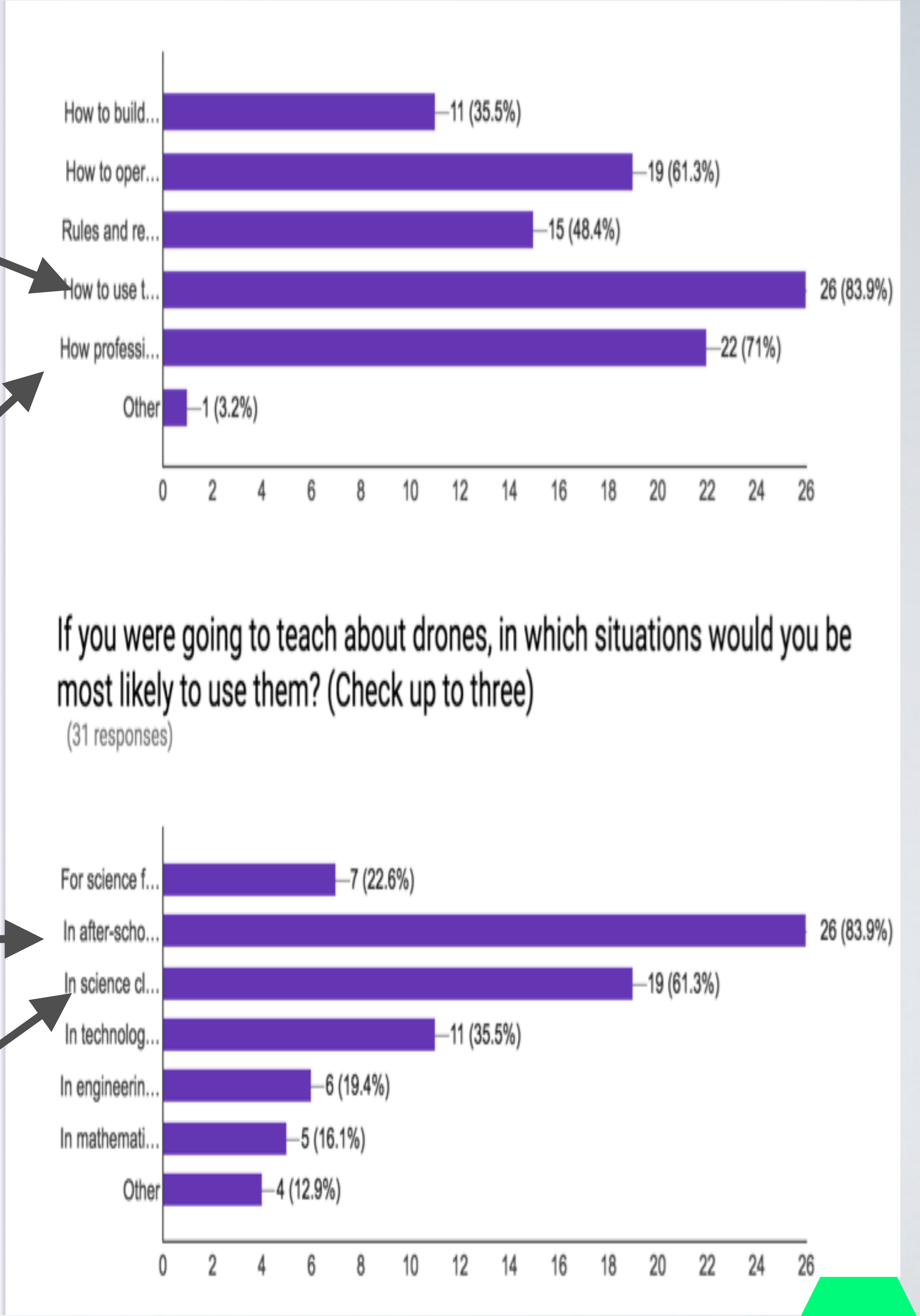
Survey Results: Teacher Interest in Using Drones

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%)



ACTIVITIES WE ARE AND ARE NOT DOING

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)

DRONES & STEM CONNECTIONS

- ❑ **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.

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B4U FLY SMARTPHONE APP : FAA APP

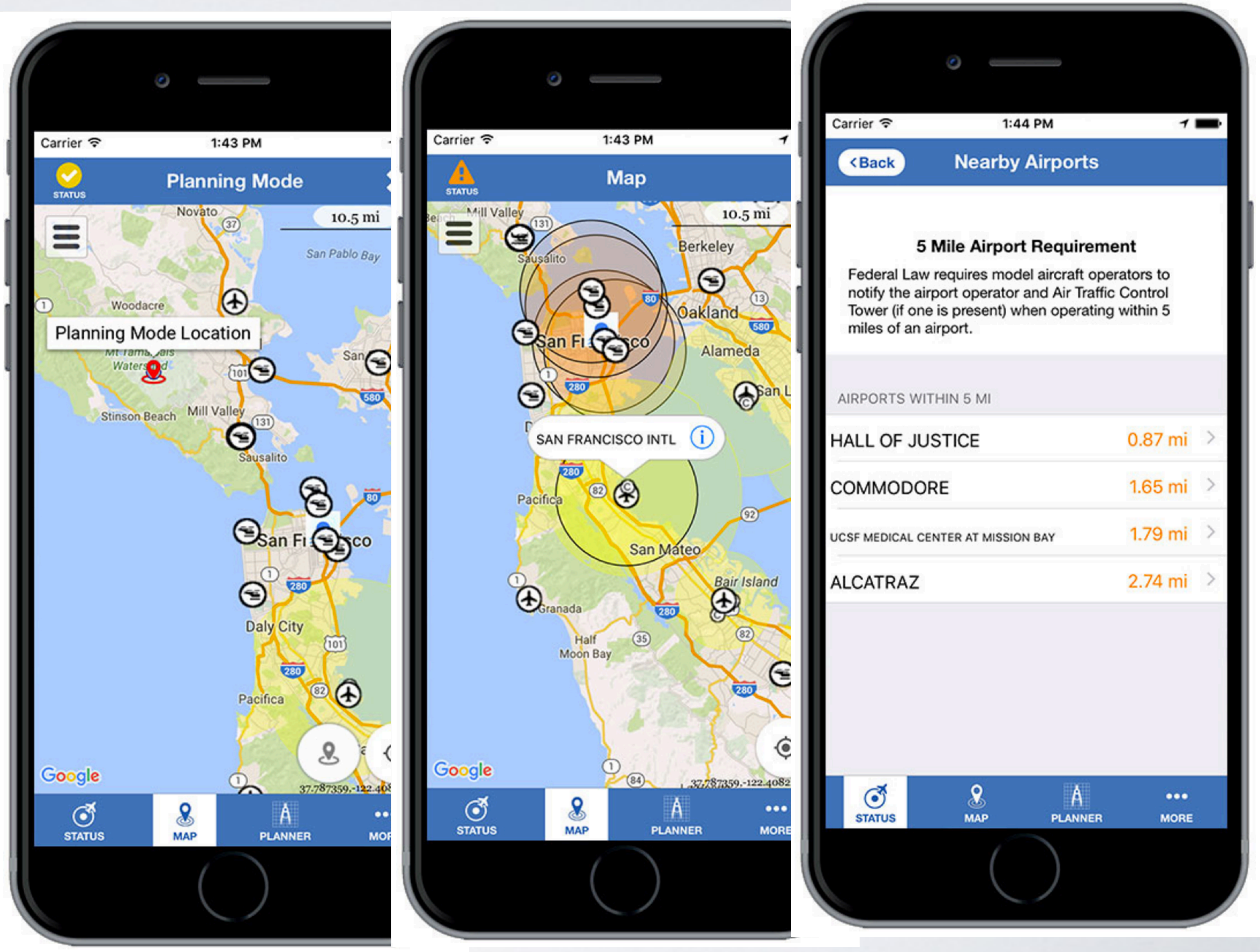
HTTP://KNOWBEFOREYOUFLY.ORG/

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 -> MAKE A PLAN

NGSS: Ask questions and define problems

Pick a question that you want to try answering with your drone.

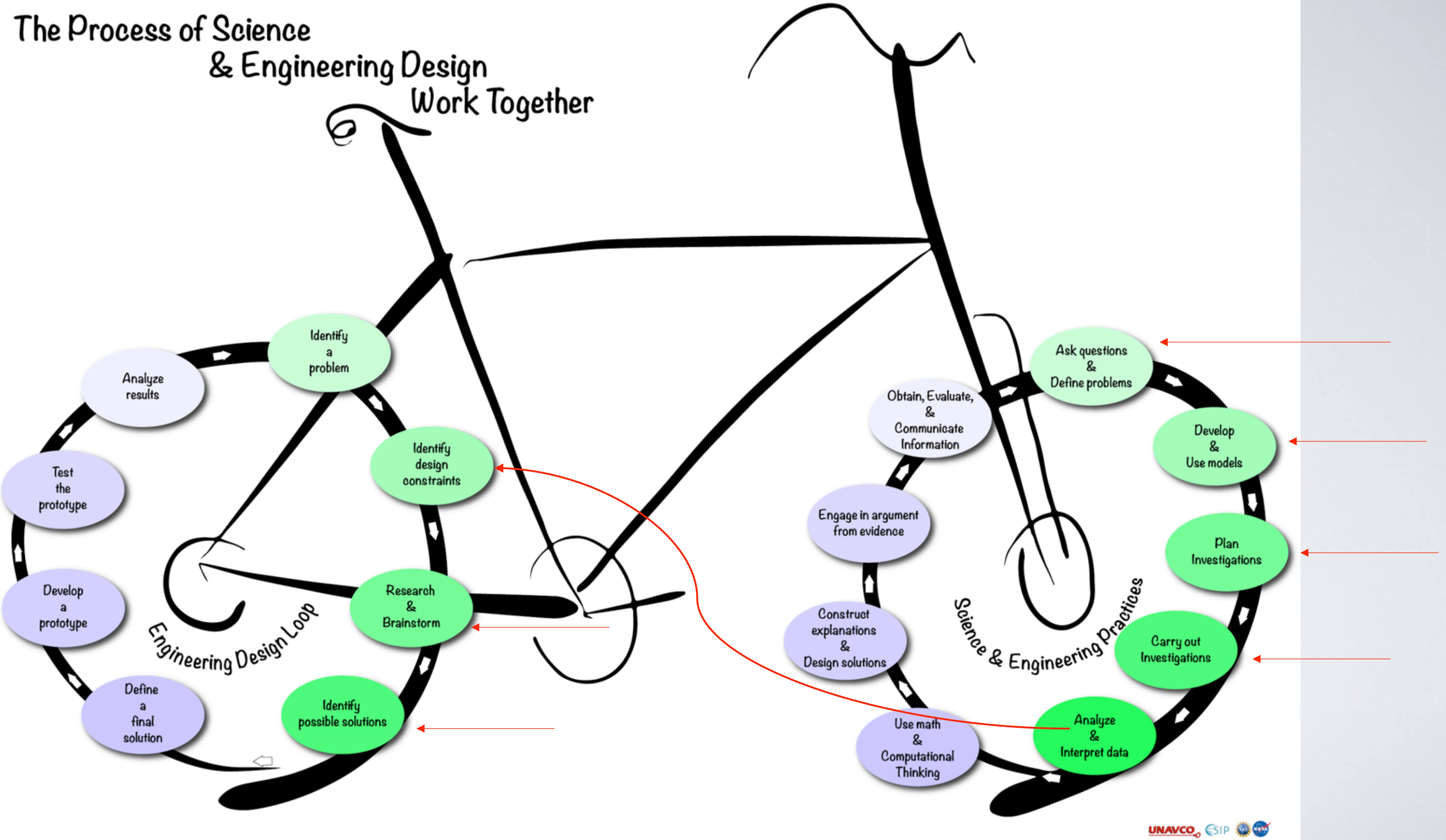
NGSS: Developing and using models

Draw a diagram illustrating your hypothesis.

NGSS: Planning and carrying out investigations.

What do you want to accomplish this flight session?

The Process of Science & Engineering Design Work Together



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Draw a diagram illustrating your hypothesis.

NGSS: Planning and carrying out investigations.

What do you want to accomplish this flight session?

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

SAFETY - STEP BACK 5X5 FOR SAFETY

- ❑ **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!

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:

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

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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?

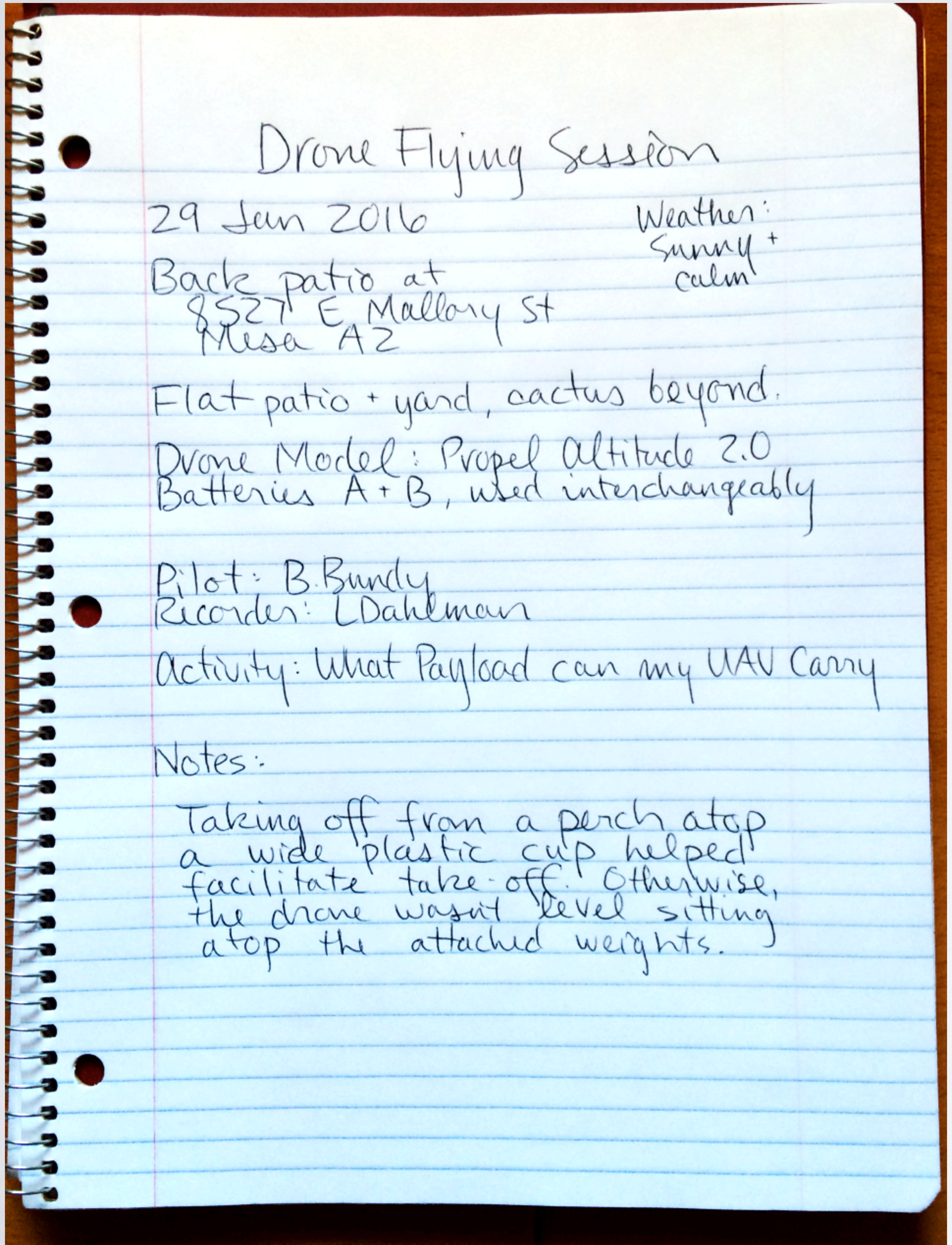
Materials: Set of washers or bolts
String
Balance, or a food or postal scale

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

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.

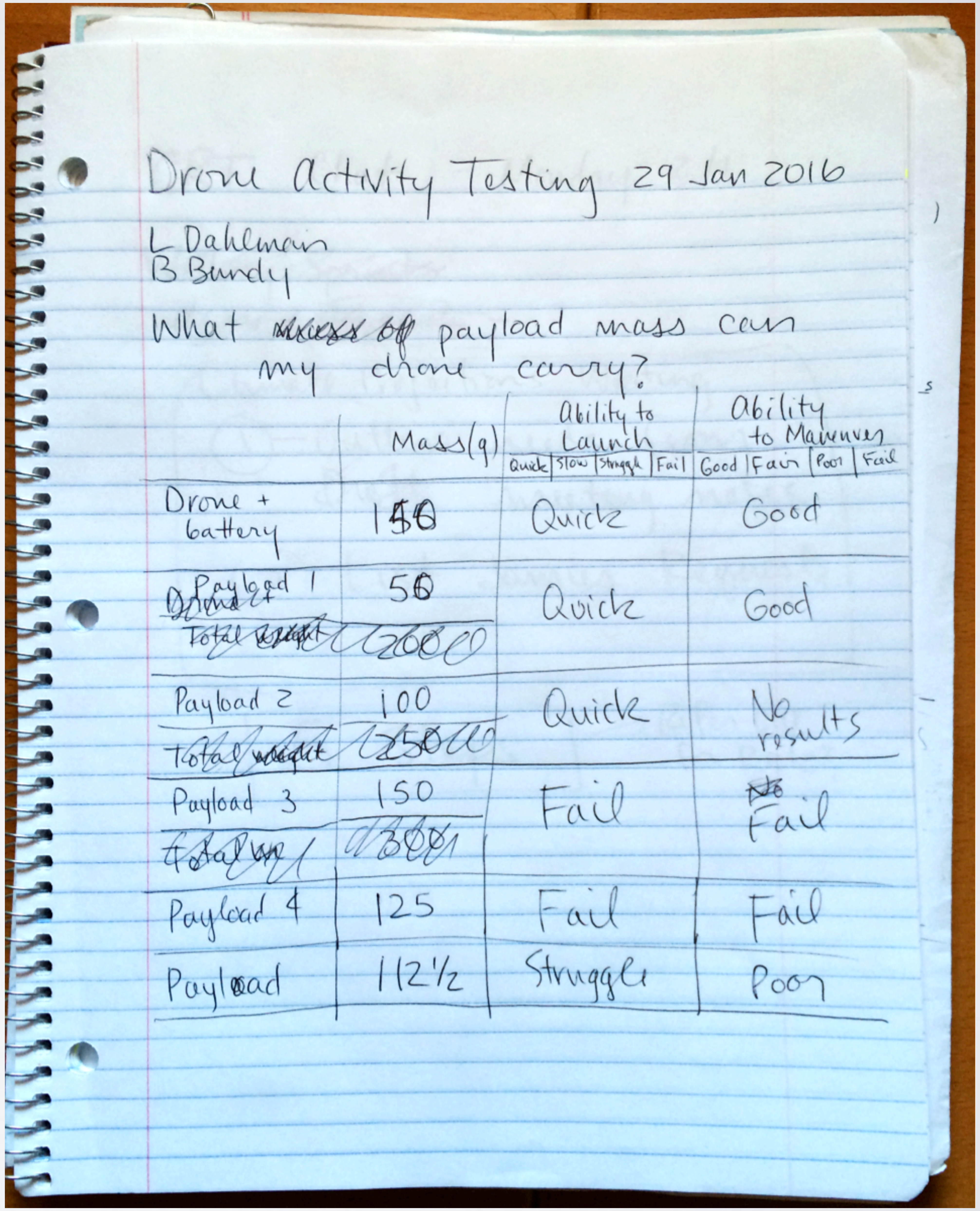
Drone Model: Propel Altitude 2.0
Batteries A + B, used interchangeably

Pilot: B. Bundy
Recorder: L Dahlman

Activity: What Payload can my UAV Carry

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 2~~ ~~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 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.

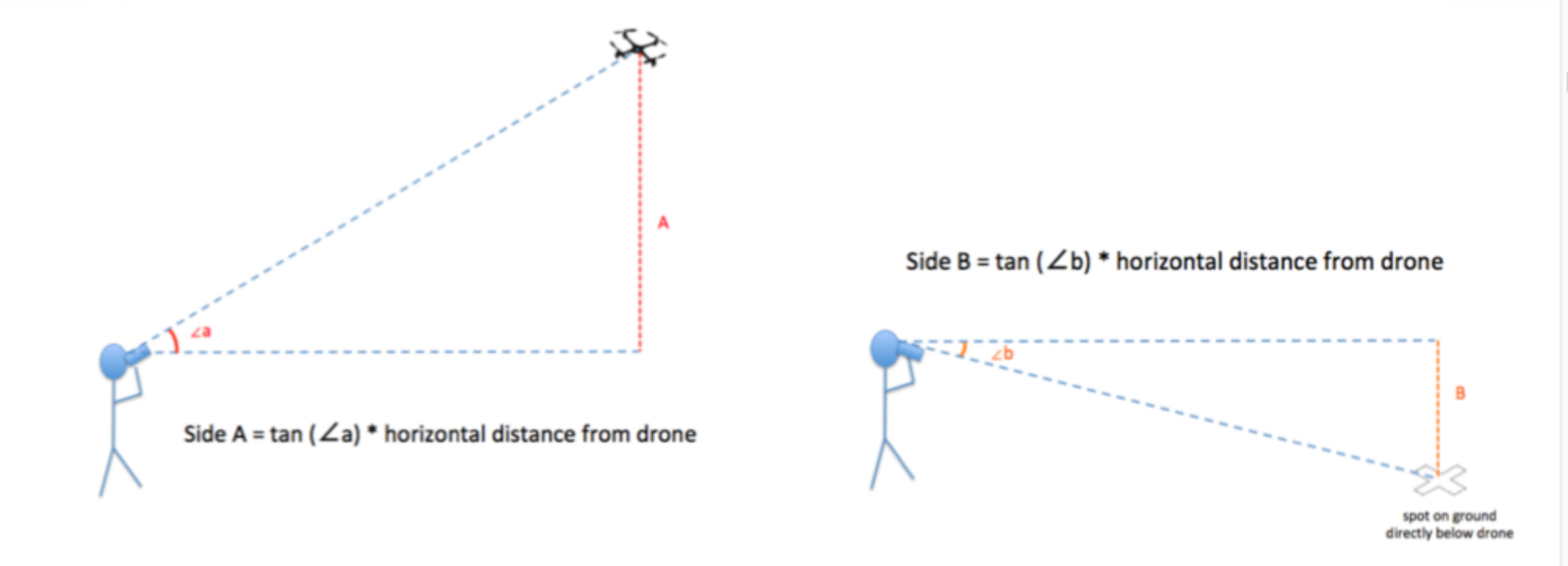
DRAFT for review Please direct feedback and/or questions to education@esipfed.org

	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?



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

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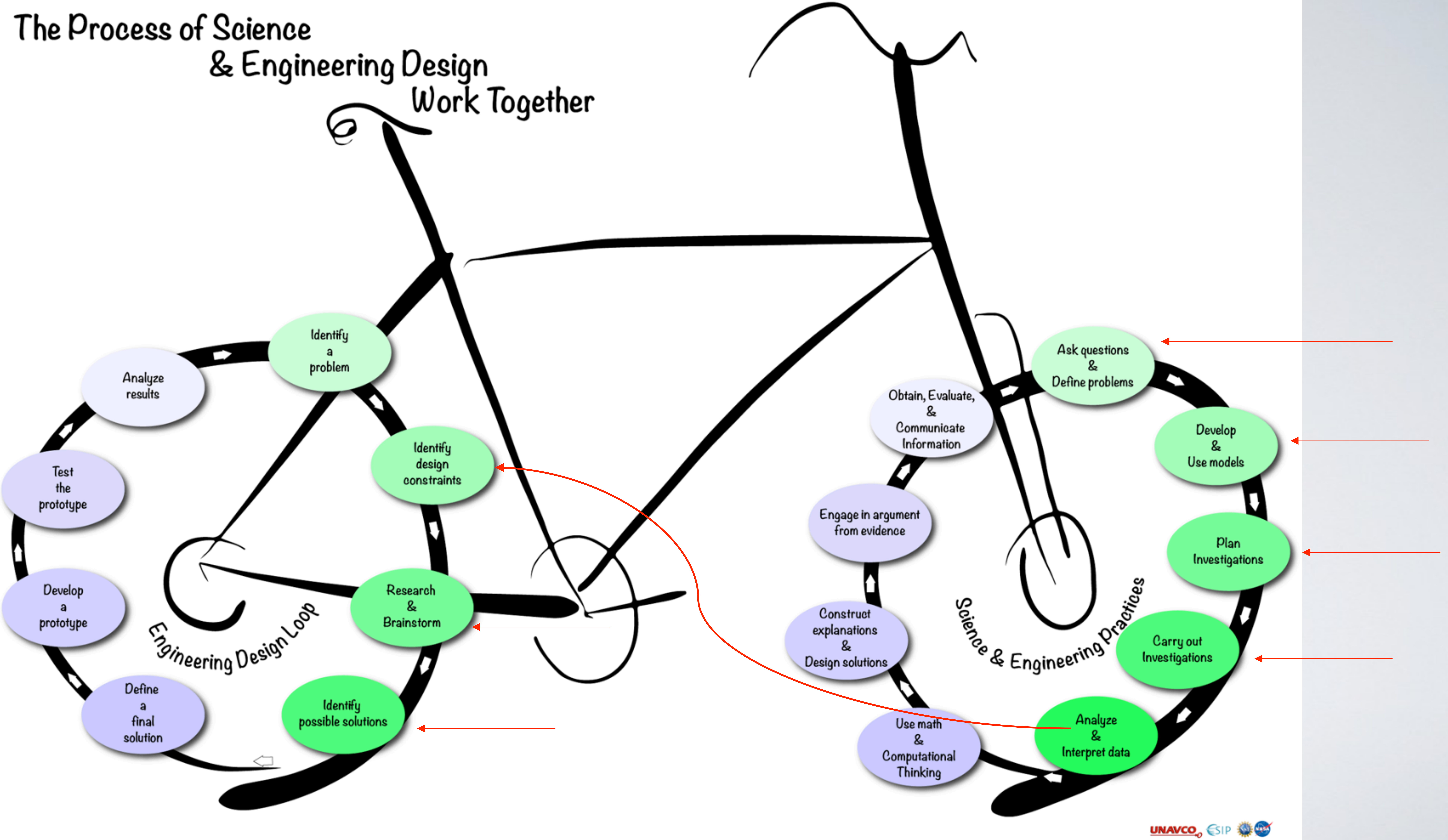
100 images

Using old math notation


The Process of Science
& Engineering Design
Work Together
Identify a problem
Identify design constraints
Research & Brainstorm
Identify possible solutions
Define a final solution
Develop a prototype
Test the prototype
Analyze results
Engineering Design Loop
Ask questions & Define problems
Develop & Use models
Plan Investigations
Carry out Investigations
Analyze & Interpret data
Use math & Computational Thinking
Construct explanations & Design solutions
Engage in argument from evidence
Obtain, Evaluate, & Communicate Information
Science & Engineering Practices
UNAVCO
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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

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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.

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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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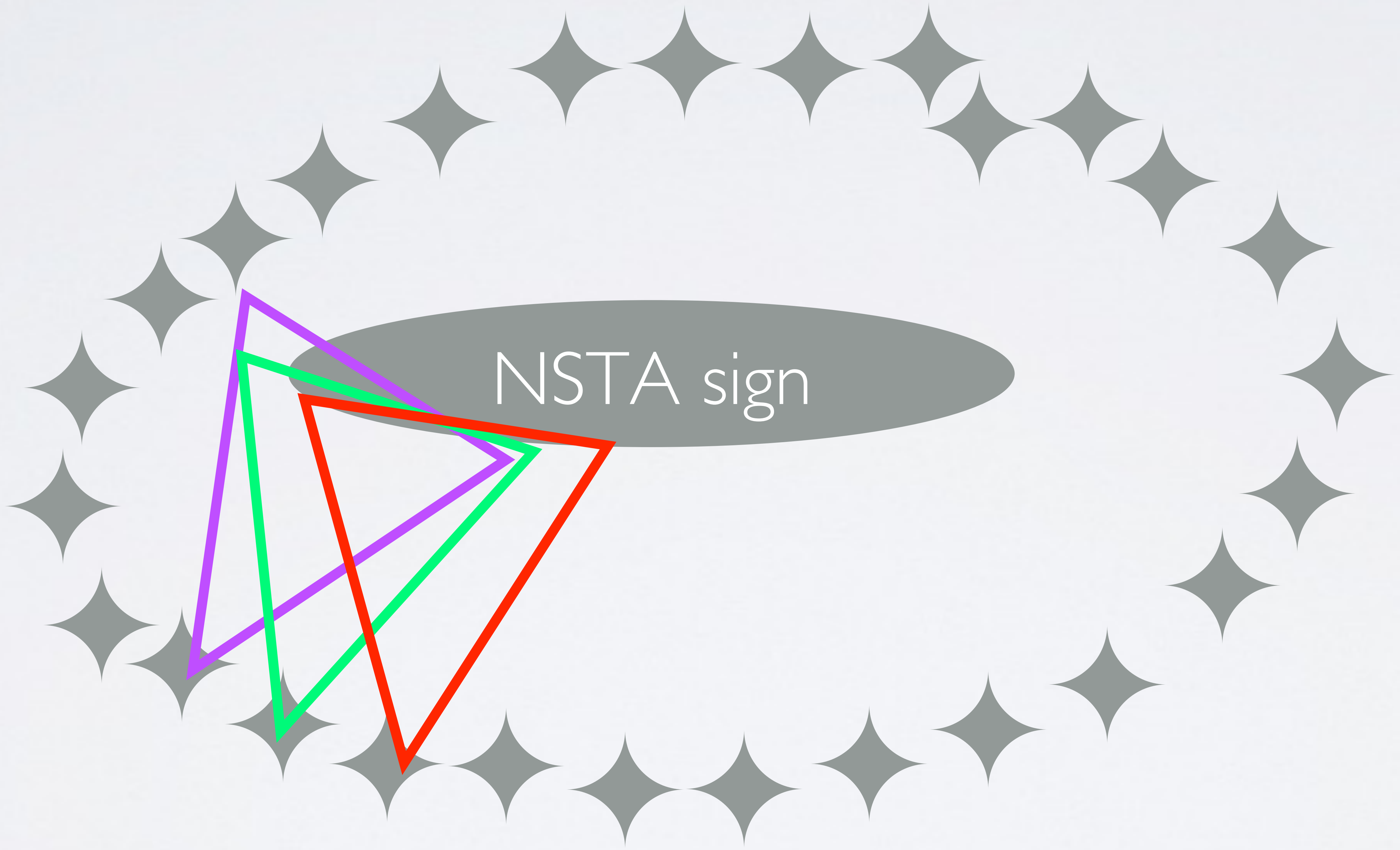
WHAT'S THE FIELD OF VIEW?

Syma X5HW recreational drone

Max Flight Time	Operating Range	Still Camera Resolution
7 minutes	50 meters	2 megapíxels

PLANNING THE OVERLAP OF PHOTOS

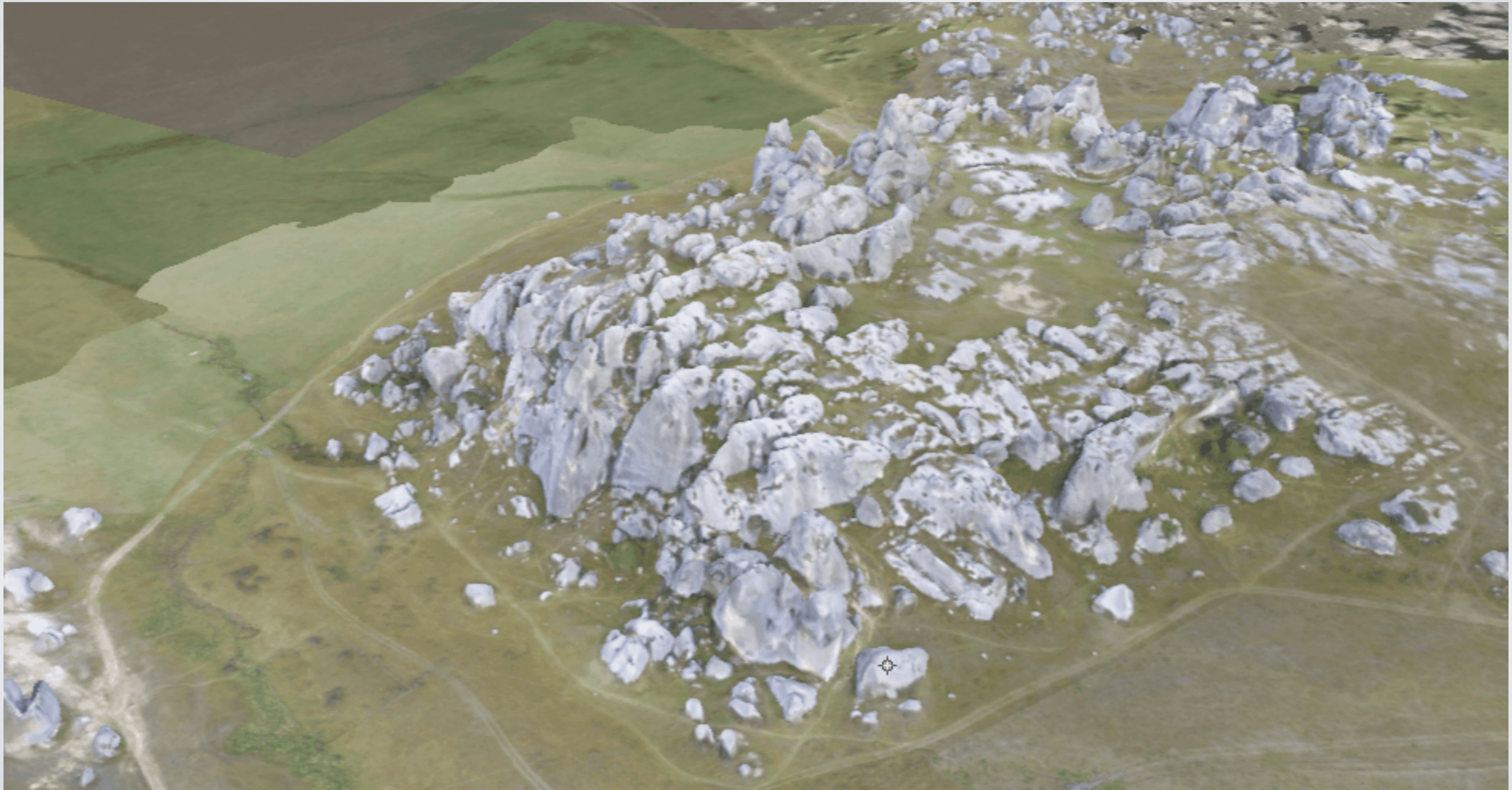


PHOTOSYNTH AND 123D AUTODESK

These are 3D models!

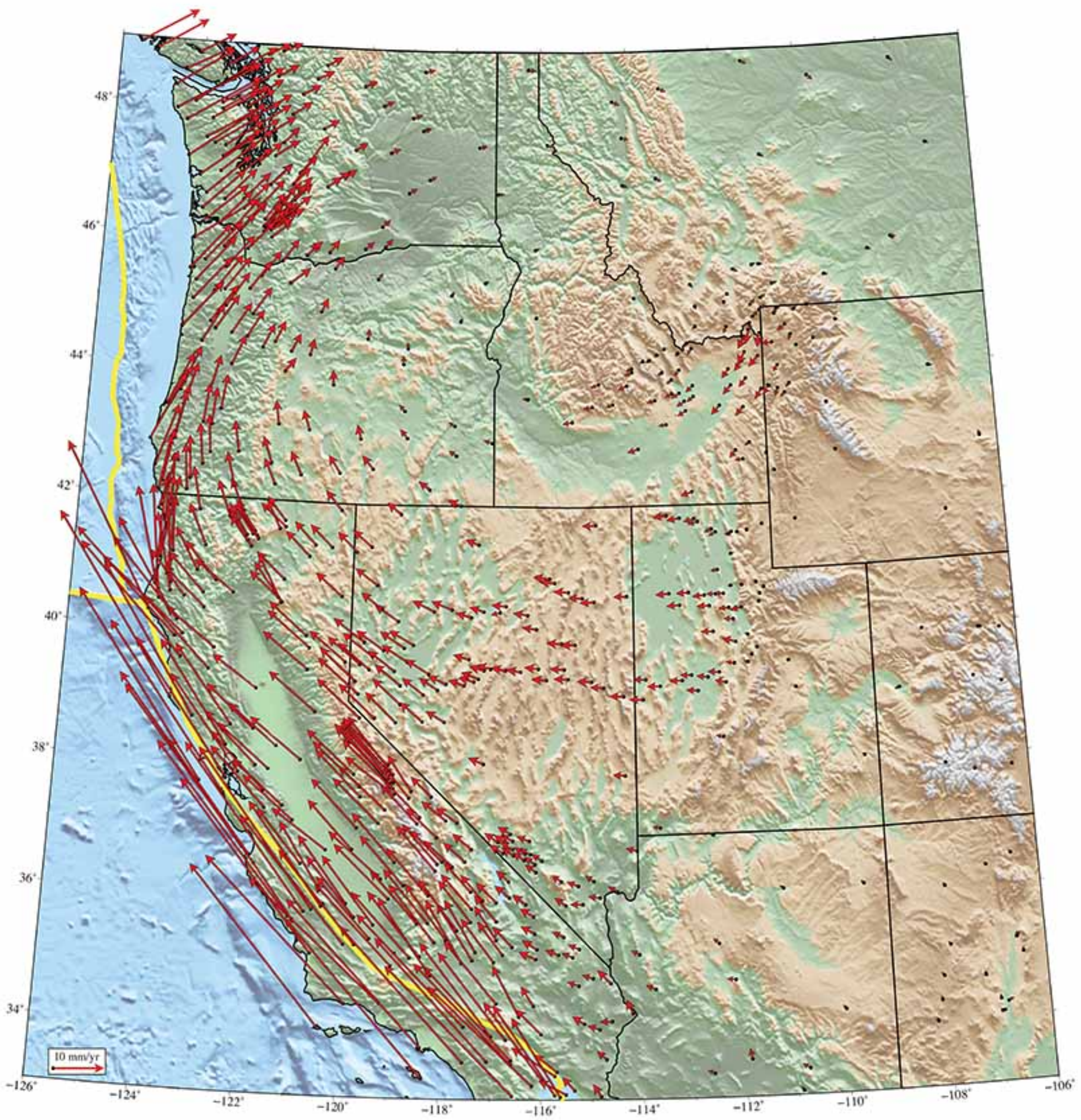
3D NEW ZEALAND

SEAN RG BARBERIE



GEODETIC IMAGING … GEODESY W/ GPS

Tectonic Motions of the Western United States



Horizontal velocities for western United States GPS stations whose data are processed by the Geodesy Advancing Geosciences and EarthScope (GAGE) GPS Analysis Centers for the Plate Boundary Observatory at New Mexico Tech and Central Washington University. Velocities are in the North America-fixed reference frame (NAM08) and calculated by the Analysis Center Coordinator at the Massachusetts Institute of Technology. The number of stations shown in California has been greatly reduced to make it easier to see regional motion. For updated velocities, search the web for UNAVCO GPS Velocity Viewer.

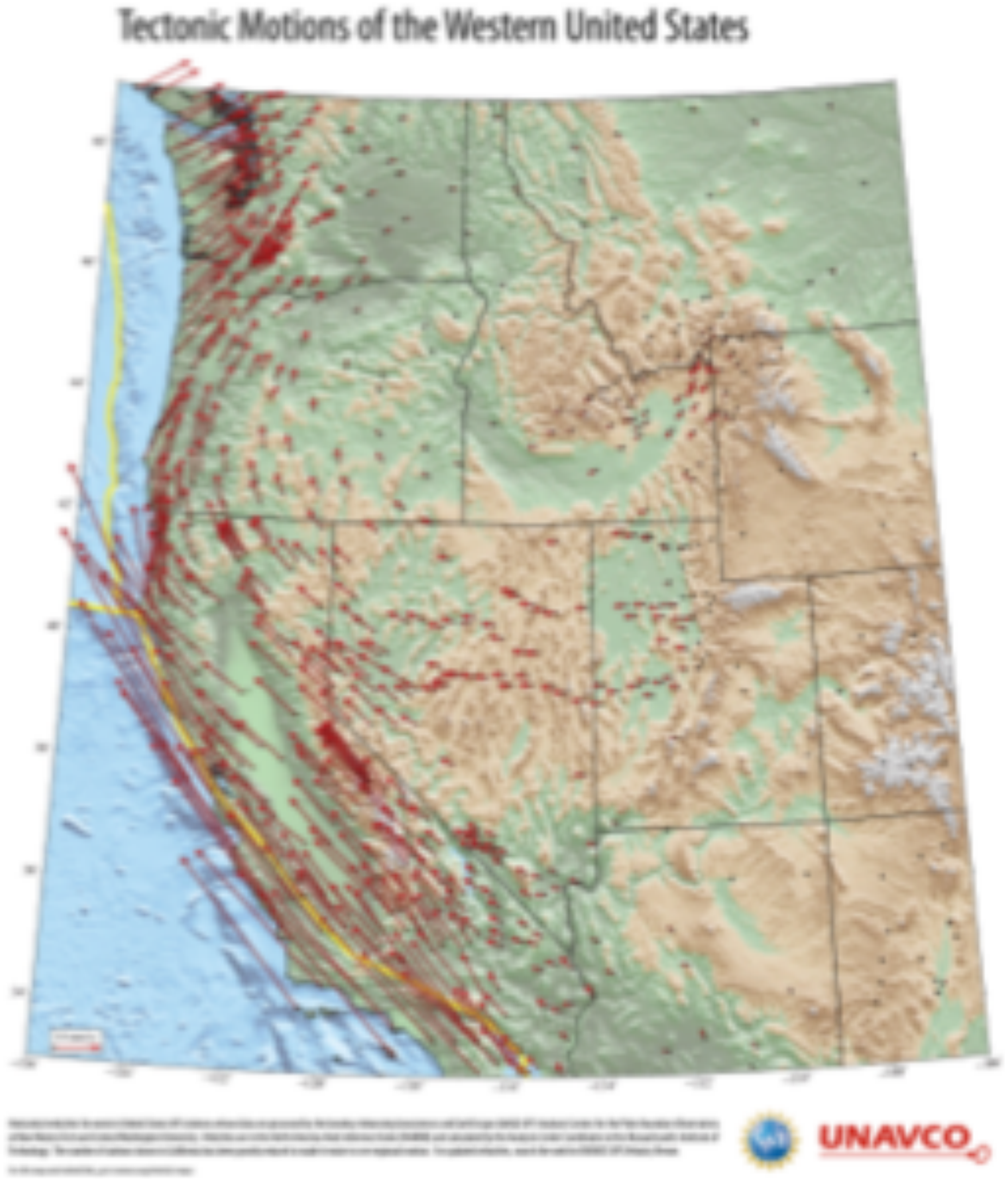
For this map and related links, go to unavco.org/velocity-maps

Explore Tectonic Motions of the Western United States GPS Data

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
   a. **from the coast to inland**,
   b. **across/ near a plate boundary** (heavy yellow lines on map),
   c. **from one side of a state to another**, and/or
   d. **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!

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.

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

Thank you for attending!

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