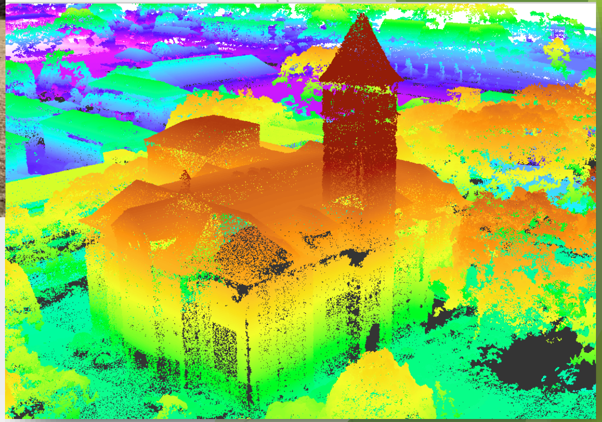
Intro to Drones for Mapping



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Software and Data

To complete the hands-on part of this workshop, you will access remotely our computers at CCGT.

Go to cuapps.clemson.edu, and log in with your regular Clemson ID and password.

On the top menu, select Desktops and GIS Cooper 406.

Next, copy the following link and paste it into a browser on your remote computer.

https://drive.google.com/file/d/1VZBE60ZBmvDPM98-wOevWDXZYIUPsNI2/view?usp=sharing

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Purpose and Goals

The purpose of this workshop is to introduce you to the use of unmanned aerial vehicles (UAV, or drones) for collecting geospatial data.

By the end of this workshop, you will have gained a basic understanding of:

- What UAVs are, commonly used sensors, and data collection capabilities
- Regulatory framework and regulations around use of UAVs
- Resources available from the Center for Geospatial Technologies
- Basic familiarity with processing images from UAVs into geospatial data products

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Outline

- Introduction to UAVs
- Regulatory Framework
- UAV Resources Available from CCGT
- Setting up A Flight and Flight Demo
- Hands-On Processing Drone Images

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What can you see?

Scale = 1:500

Resolution = 15 cm/pix

What can you see?

Scale = 1:500

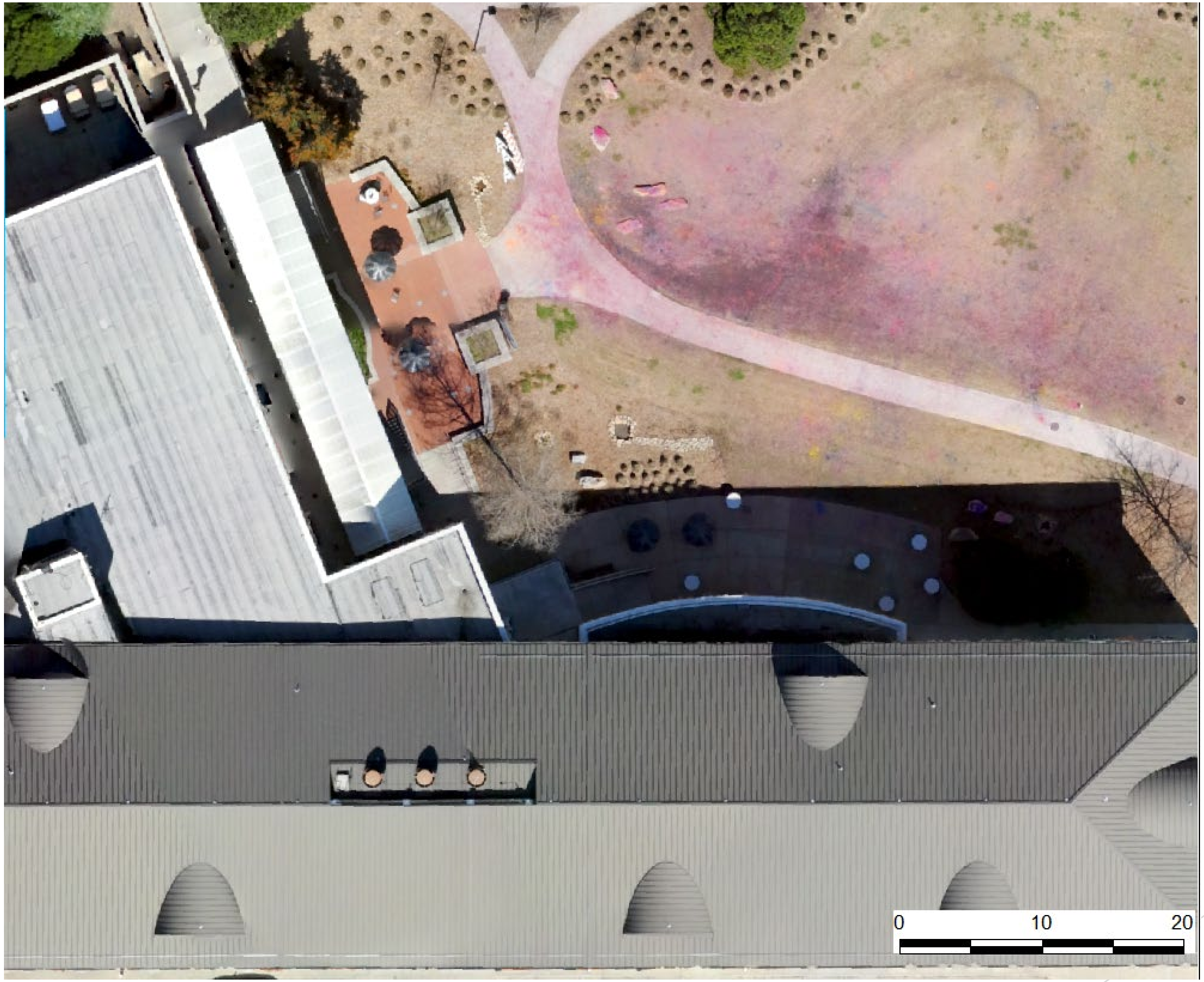
Resolution = 8 **mm**/pix

Folly Island, SC
March 25, 2017

What can you see?

Scale = 1:300
Resolution = 15 cm/pix

What can you see?



Scale = 1:300
Resolution = 2.5 cm/pix

Hendrix Student Center
March 4, 2018

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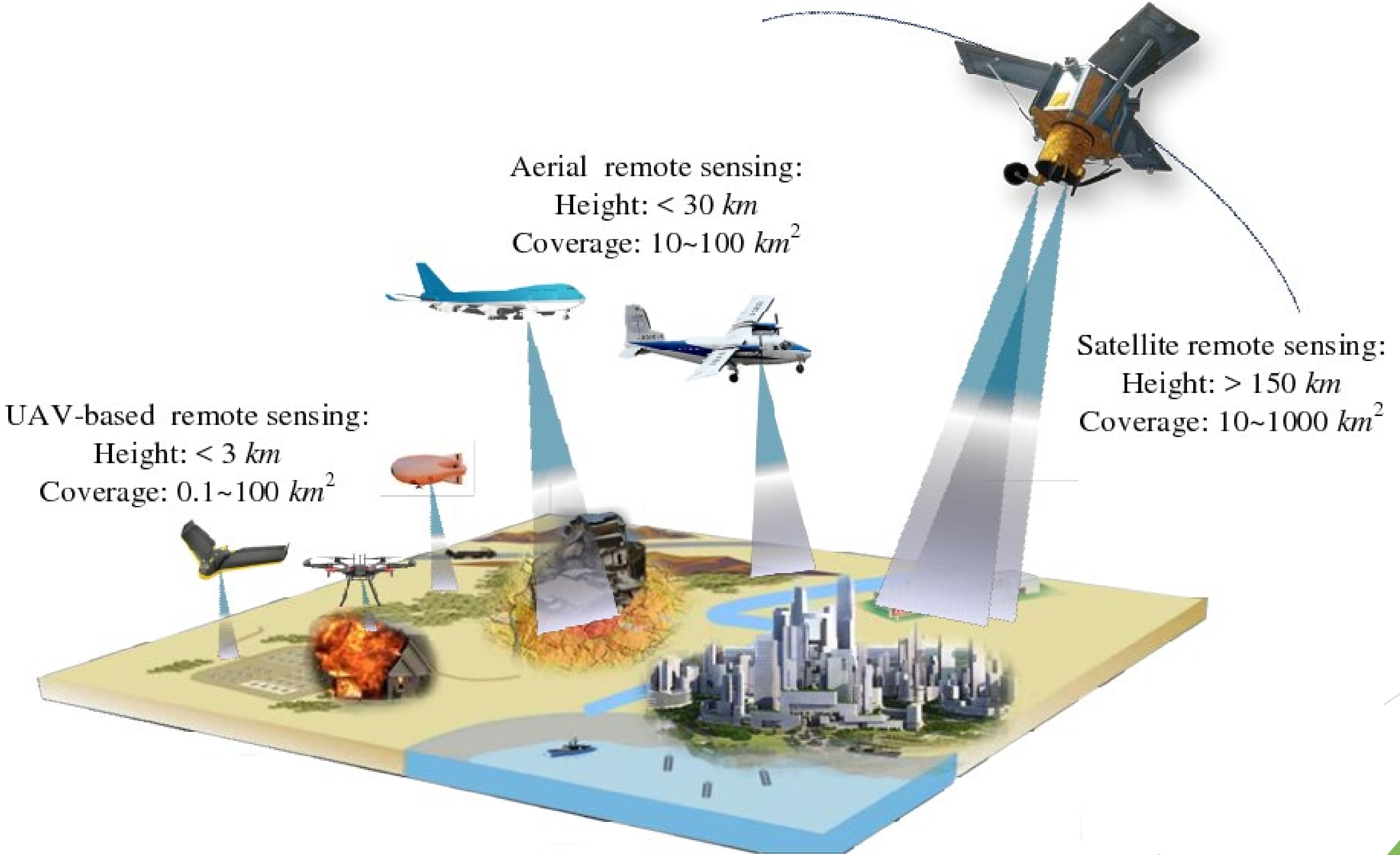
Remote Sensing Platforms:

Low-altitude UAV| Manned Aviation | Satellite



Source: IEEE Geoscience and Remote Sensing Magazine, 2019

What are UAV? UAS? Drone?

An Unmanned Aerial Vehicle (UAV) is commonly referred to as a **drone**

- Remotely piloted aircraft – fixed wing, multi-rotor
- May use GPS & other sensors to fly pre-programmed route
- Usually carry sensor payload(s)

- Common terms also include:
  - **Unmanned Aerial Systems** (**UAS**)
    - Includes aircraft, controller, communication system
  - **Small Unmanned Aerial Systems** (**sUAS**)
    - Weight of 0.55 – 55 lbs.

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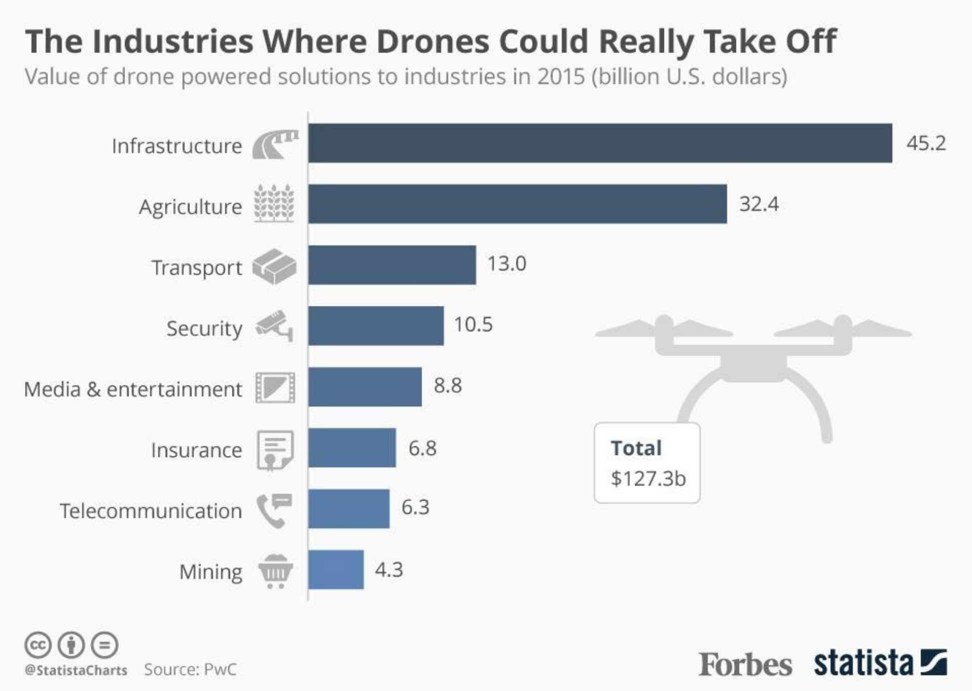
Industry Forecast

- The economic value of drones is predicted to reach **$100 billion** and create over **100,000 jobs** by the year 2025 (Goldman Sachs).
- In South Carolina alone, the economic value of drones is predicted to reach almost **$600 million** by 2025.
- Innovations are expected **across industry** lines, with fields like **precision agriculture** and public safety leading expenditures in drone use.
- These “flying robots” will expand the possibilities for making measurements and **transform** how research is performed.



PwC Global Report on the commercial applications of drone technology, 2016.

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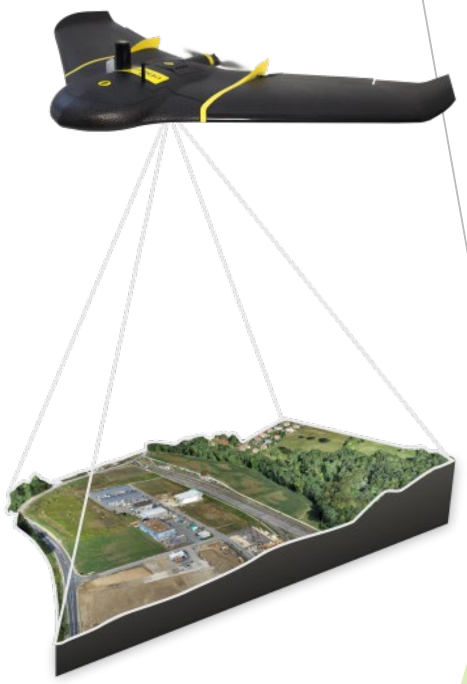
UAV as Data Collection Platform

- A UAV mounted with GPS and sensors can be used for capturing a variety of geospatial data
  - Up-to-date, high-resolution (!) aerial imagery
  - Digital elevation (terrain and surface) models
  - 3D point clouds
  - Multispectral imagery
  - Many others…
- Captures data directly (e.g. LiDAR) or is **processed** (e.g. photos) to create GIS products
- Coverage of areas between conventional aerial photography and on-the-ground surveying
  - Up to ~500 acres in a flight with a fixed-wing UAV



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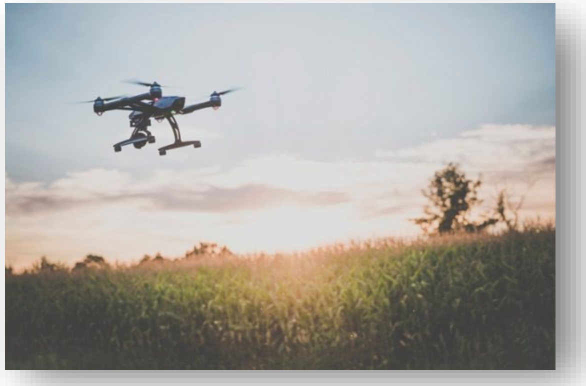
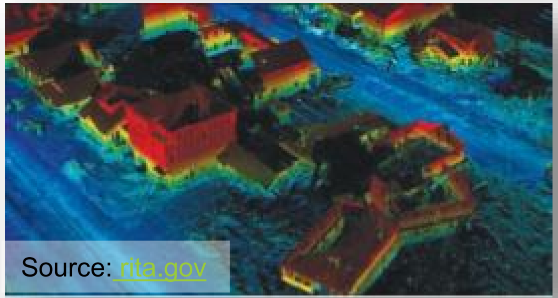
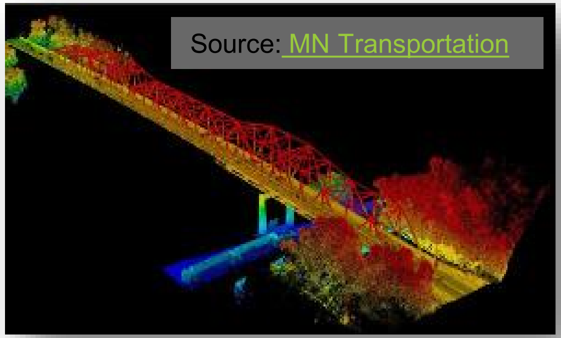
Applications







Architecture

Forest planning and management

Park management and tourism

Cellular network planning

Watershed delineation

Flood modeling

River channel surveying

City planning

Storm water management

Civil engineering

Archaeology

Geologic studies Fault monitoring

Law enforcement

Search and rescue

Solar energy planning

Slope stability

Coastline management

Disaster relief

Dune mapping and monitoring

Tunnel surveying

Agriculture

Cloud mapping

Utility management

Viewshed analysis

Mining

Glacial studies

Airport infrastructure

Railroad engineering

Military

Space exploration & mapping

Cloud studies

Pollution modeling

Facility management

As-built documentation

Ship building

…and many more!

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Types of UAVs

Fixed Wing

- “Plane” style
- Generates lift with wings, steers with flaps
- Less maneuverable
- Covers larger areas in single flight, better battery life
- Tend to be “more expensive”
- More difficult to fly manually

Multi-rotor

- “Helicopter” style
- Multiple rotors provide lift and steering
- Highly maneuverable, can hover and rotate
- Shorter battery life, smaller areas than fixed-wing
- Can be “less expensive”

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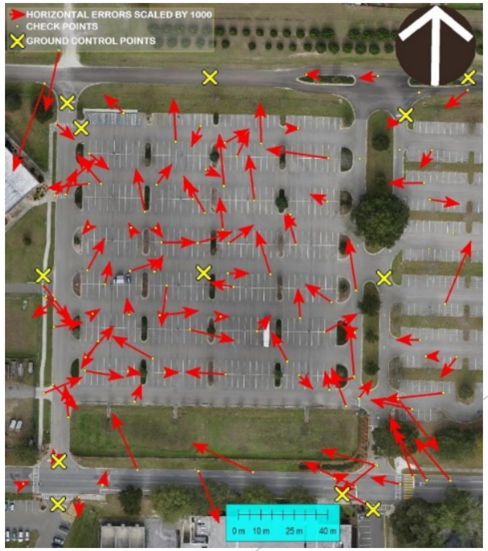
Positioning and Autopilots

Use of **integrated flight systems** allows for fully automated takeoff, flight, and landing

- **GPS** to navigate pre-programmed route, trigger data collection
- **Failsafe measures** for lost communication, battery failure
- **Obstacle avoidance** to prevent collisions

High-accuracy GPS available for UAVs

- RTK, PPK systems give cm-level accuracy
- Accuracy of position data affects accuracy of georeferenced data



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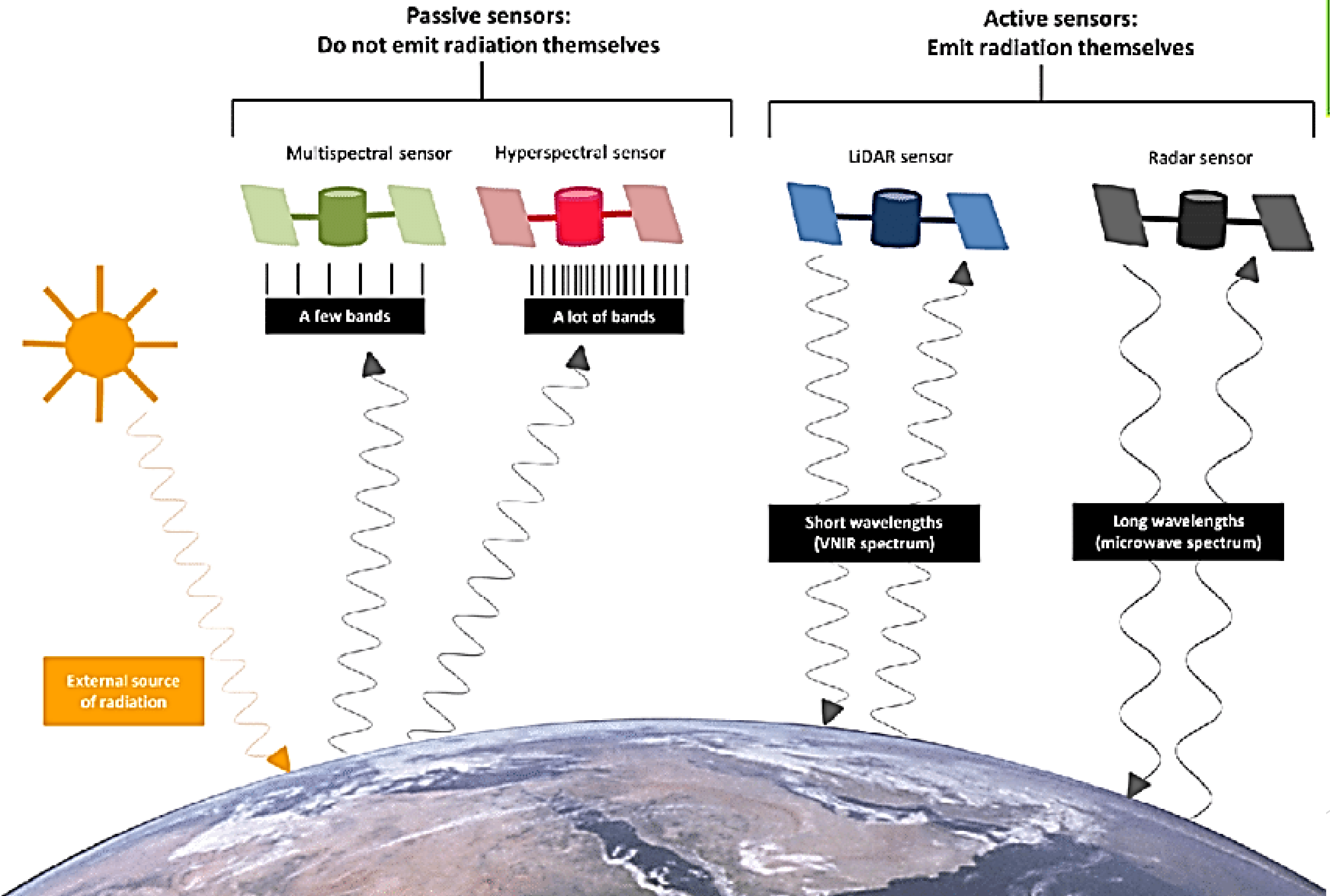
Quiz 1: Introduction to UAVs

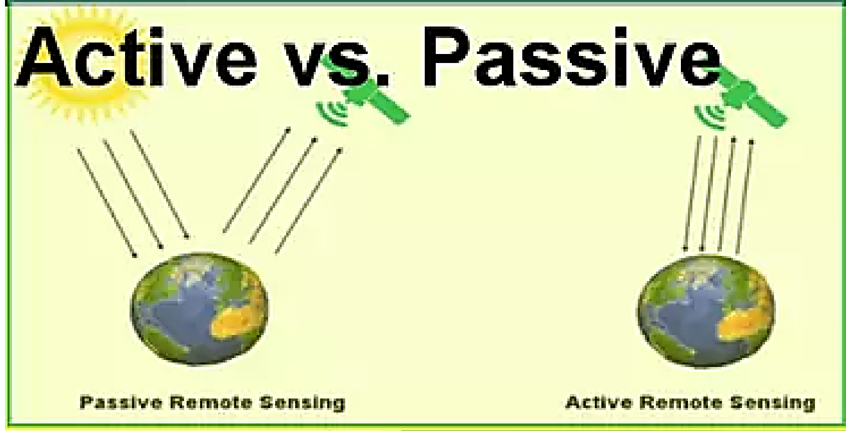
This is a required quiz you must pass in order to obtain certified hours for this workshop.
You can re-take the quiz until you get all the answers right. Must have all answers correct to get a pass on this quiz.

https://forms.gle/khcrj3g8j9AXWhkq9

Commonly Used Sensors

Passive Vs. Active Sensors





Common Sensors RGB Camera

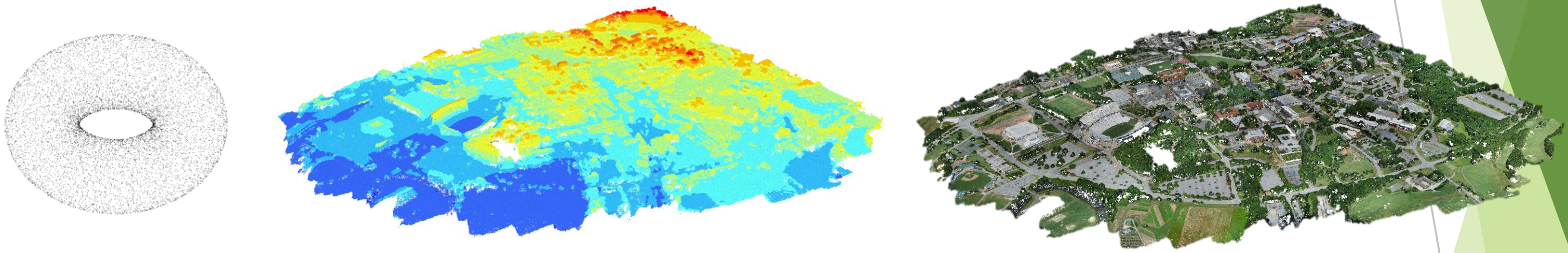
The most common sensor is the digital RGB camera

- Takes photos/video in visible spectrum.
- Images used directly or photogrammetrically processed to create geospatial data
- Many UAV cameras for photography are suitable for mapping
- Need intervalometer or software trigger

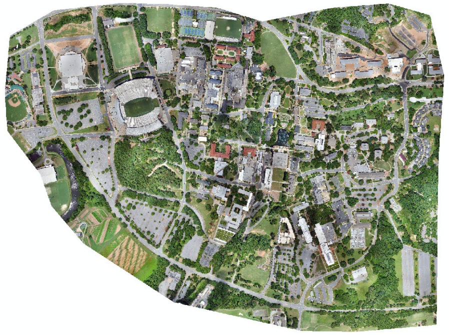
Common Sensors RGB Camera

Images are used directly or photogrammetrically processed using **Structure from Motion** (**SfM**) software to create geospatial data

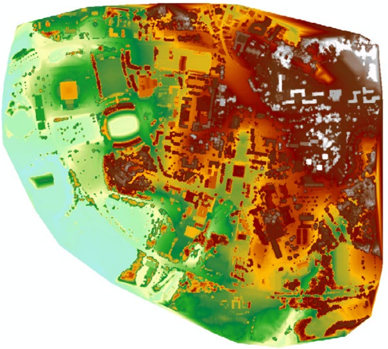
Still Images and Video



Point Clouds



True-color Orthomosaic



Digital Elevation Model

3D Textured Mesh

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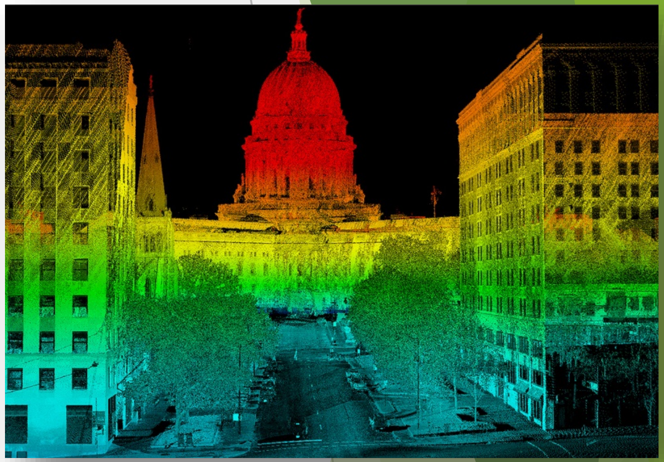
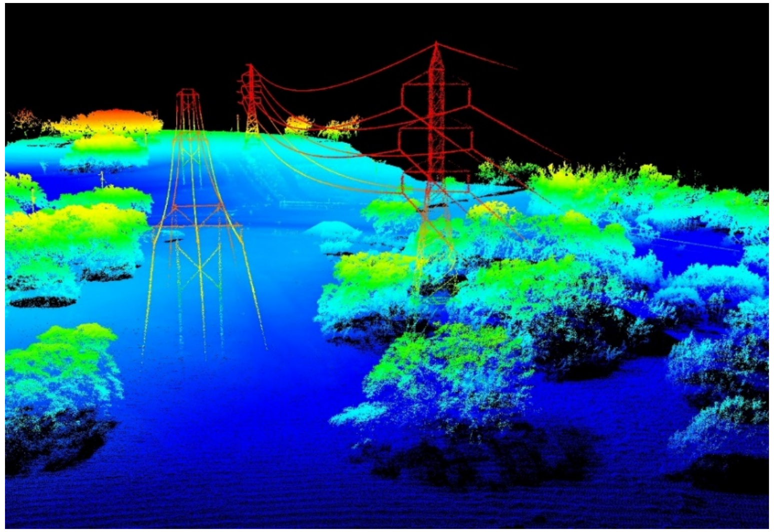
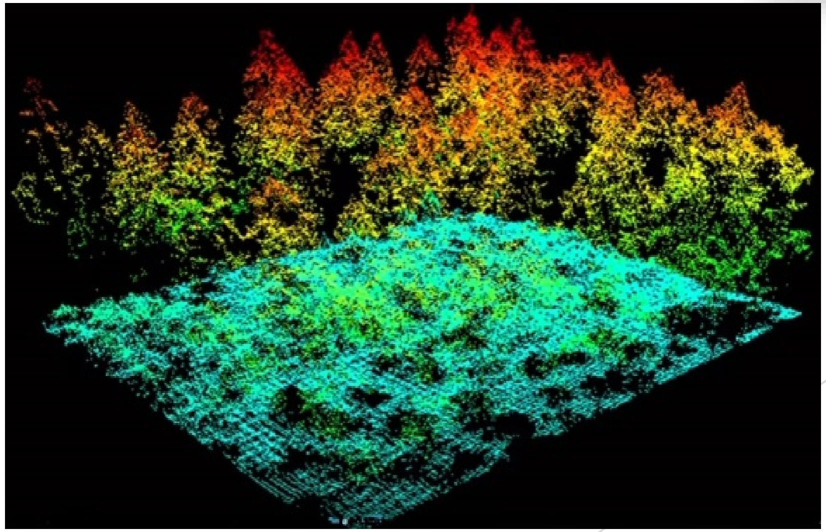
Common Sensors LiDAR Scanner

- **Li**ght **D**etection **A**nd **R**anging
- Active remote sensing system which emits laser pulses for range finding
- Maps features as a 3D **point cloud**
- Used directly or processed to create elevation models and other products
- Requires high-accuracy GPS, inertial measurement unit to accurately locate points







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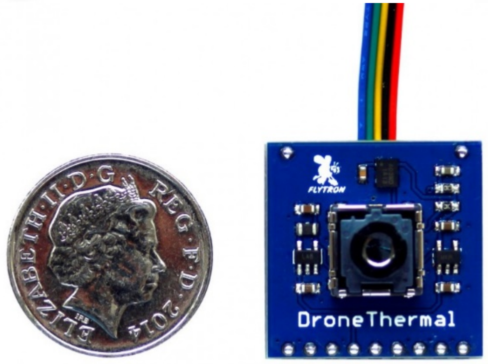
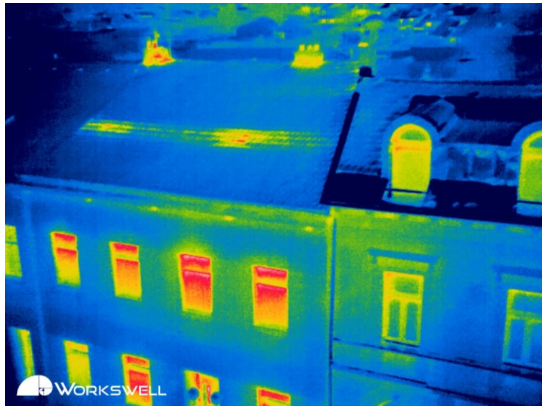
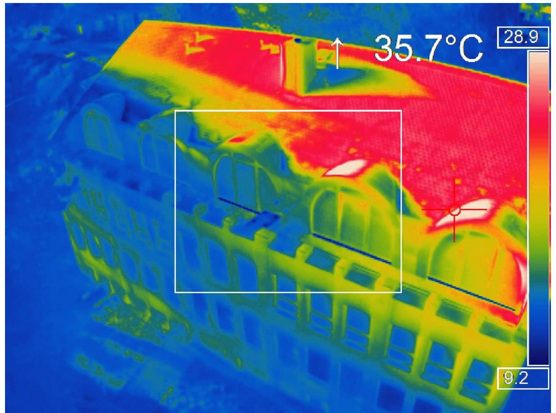
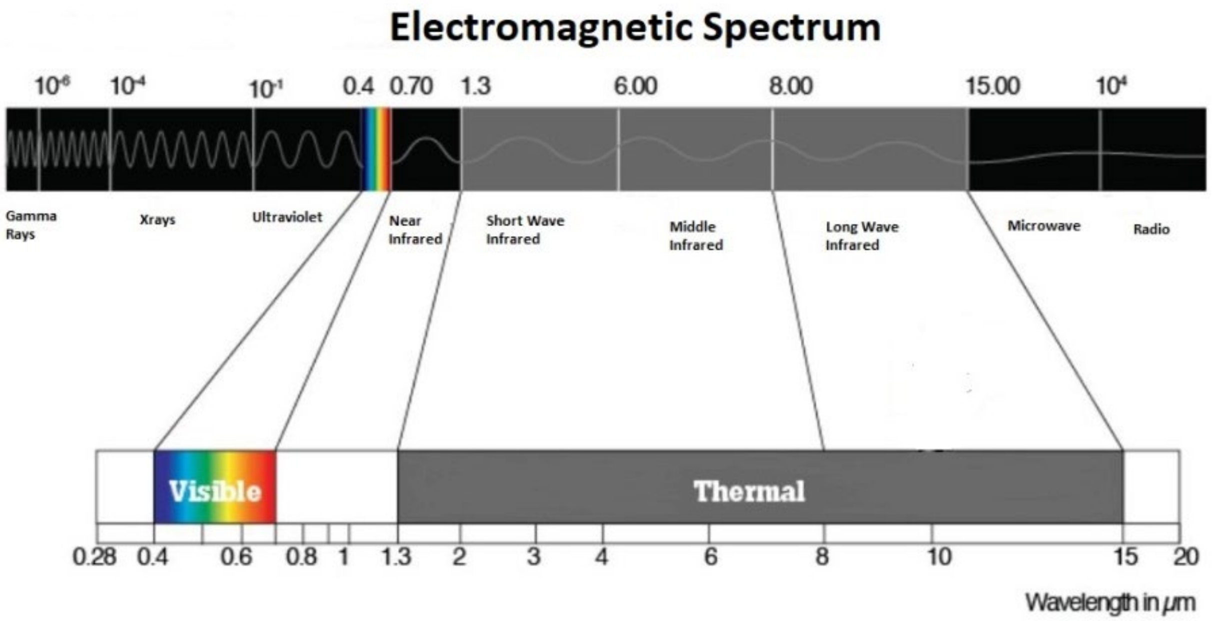
UAV Sensors: Thermal Camera

- Thermal Cameras capture photo/video in the infrared spectrum
- Lower resolution than RGB cameras
- Not as useful for photogrammetric processing
- Monitoring relative temperature changes









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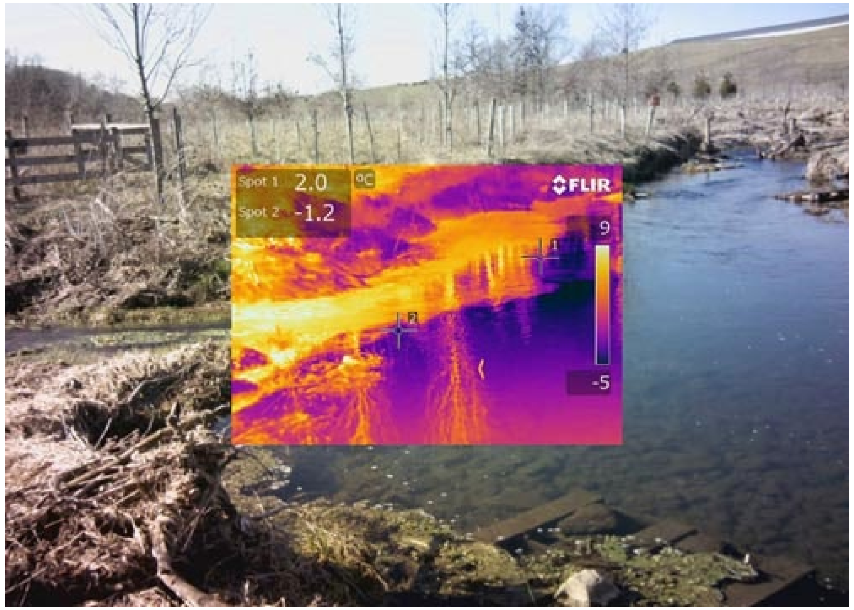
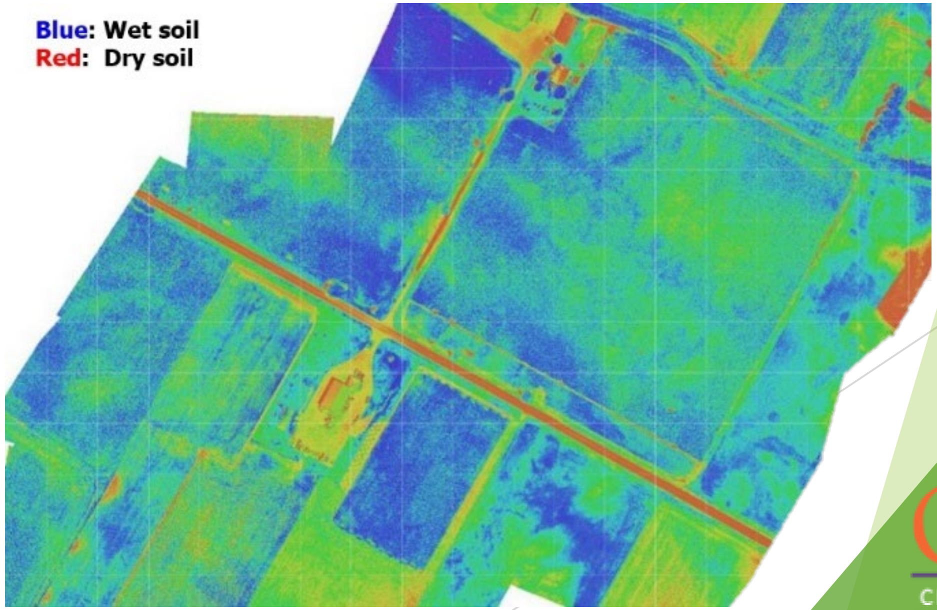
UAV Sensors: Thermal Camera

Temperature images are useful for:

- Building inspections
- Locating and tracking wildlife
- Measuring soil moisture
- Characterizing surface and ground water interactions





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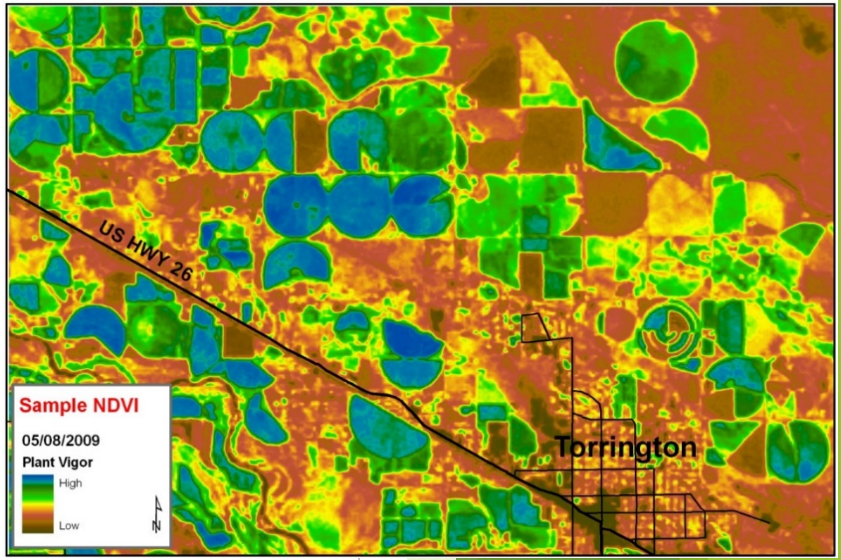
UAV Sensors: Multispectral Camera

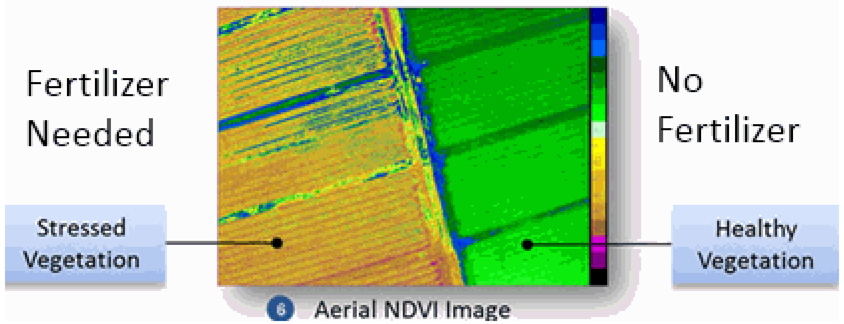
- Multispectral cameras capture images in visible and infrared spectrum (>700 nm)
- Similar resolution to RGB cameras, can be photogrammetrically processed
- Processed to create vegetative health index images, e.g. NDVI

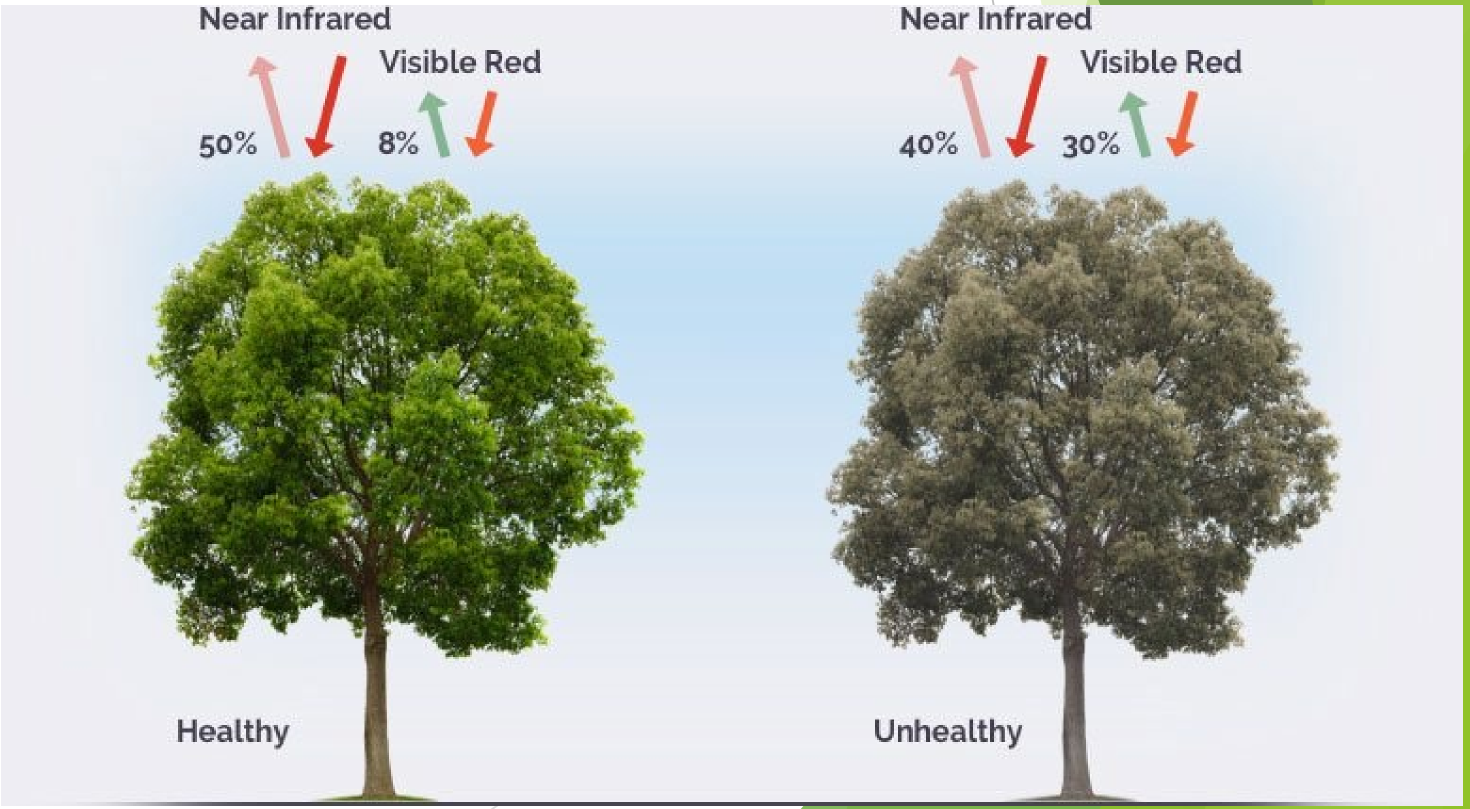
Parrot Sequoia (72 grams)

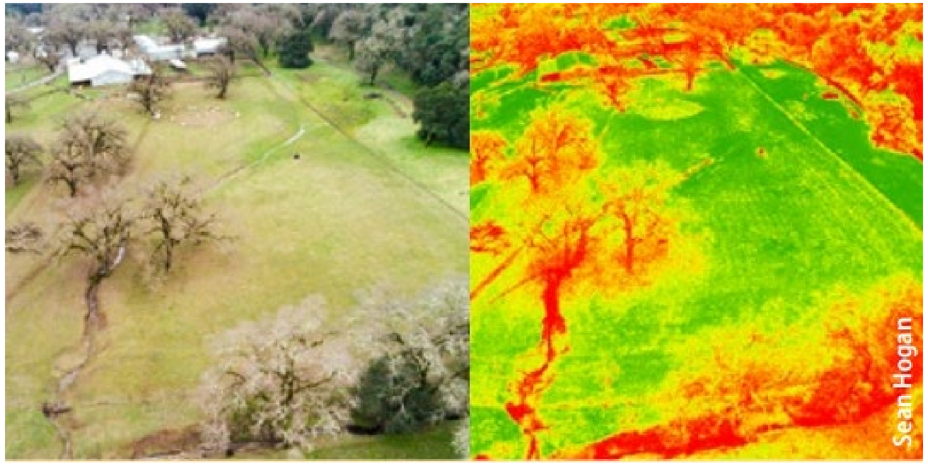
UAV Sensors: Multispectral Camera

- Multispectral cameras capture images in visible and infrared spectrum (>700 nm)
- Similar resolution to RGB cameras, can be photogrammetrically processed
- Processed to create vegetative health index images, e.g. NDVI



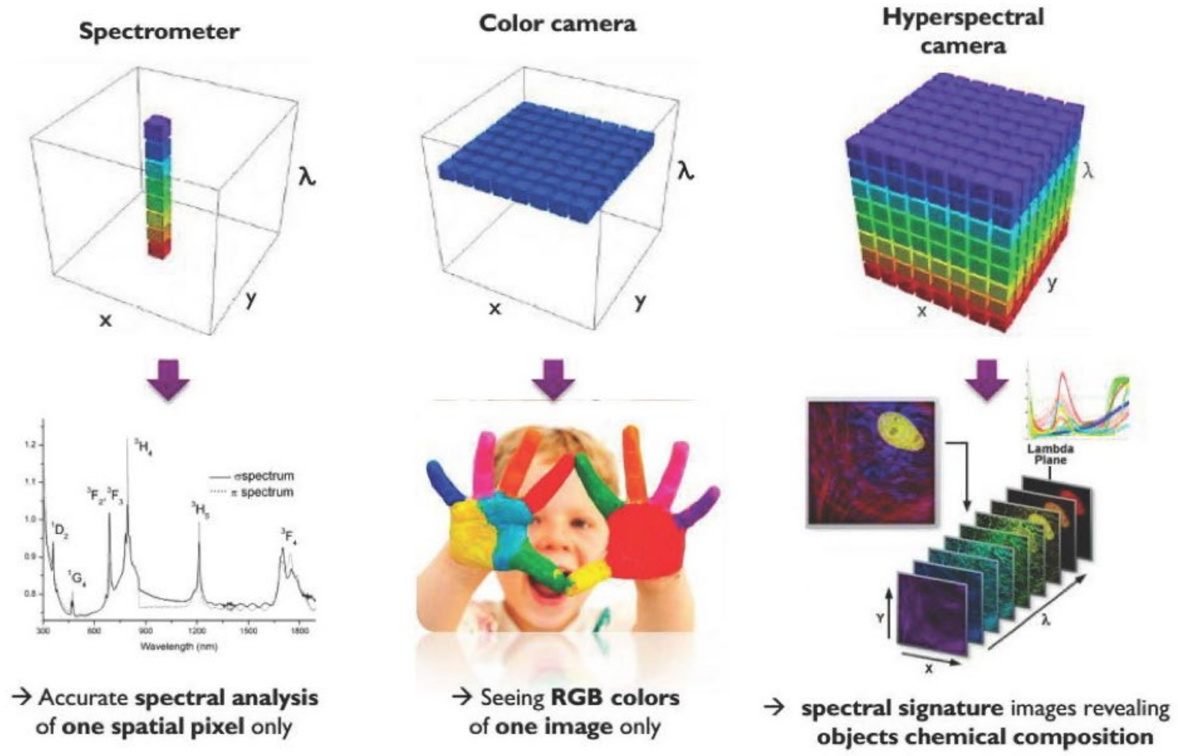






UAV Sensors: Hyperspectral Sensor

- Hyperspectral sensors are spectrometers which measure reflected light across many (50+) narrow spectral bands (300-2,200 nm)
- Create a rich data-cube composed of spectral image layers
- Enables precise analysis of shifts in particular spectra



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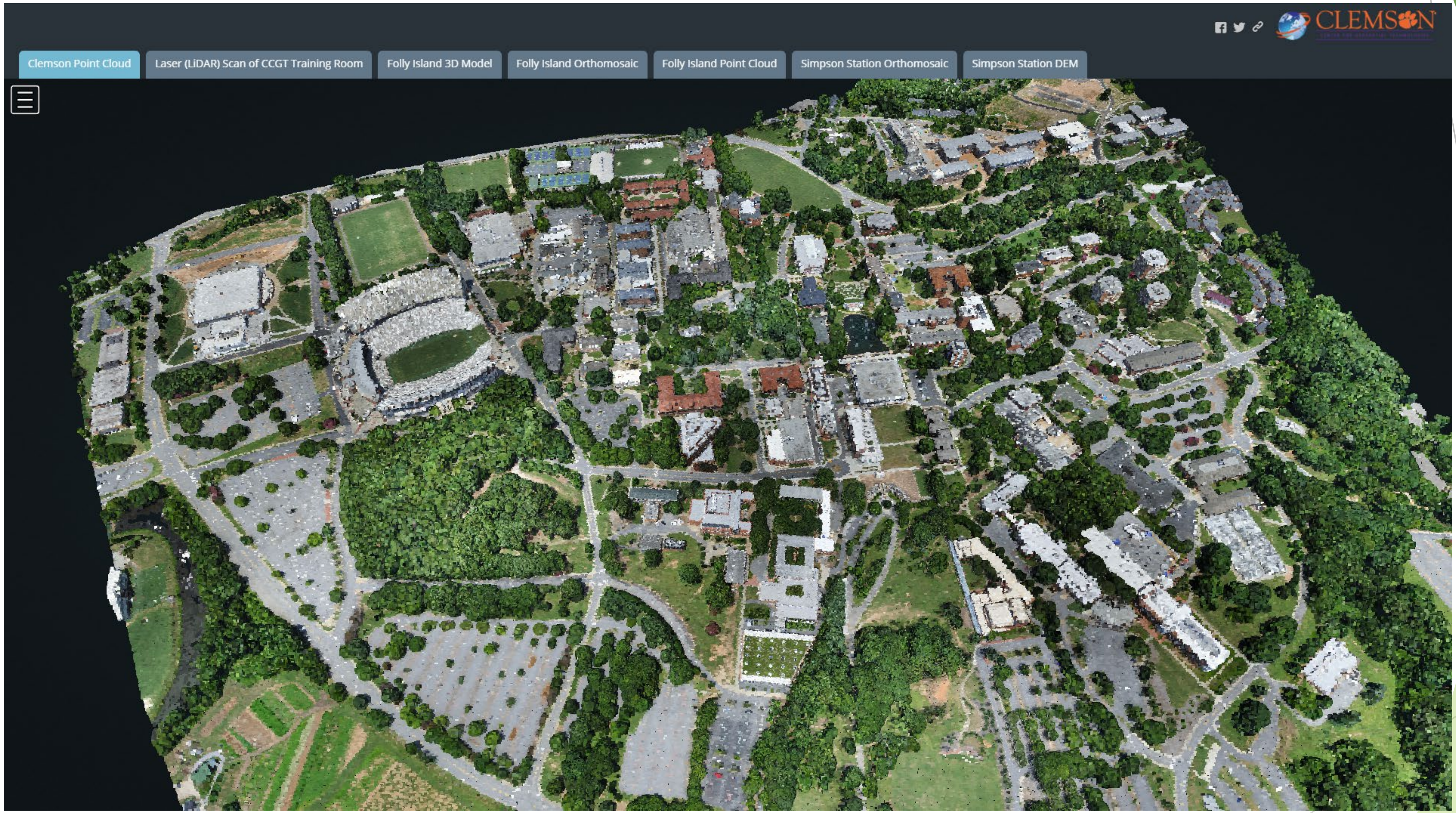
Examples of Data Products



www.bit.ly/ccgtuavdata

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Quiz 2: Commonly Used Sensors

This is a required quiz you must pass in order to obtain certified hours for our GIS Fundamentals Series.
You can re-take the quiz until you get all the answers right. Must have all answers correct to get a pass on this quiz.

https://forms.gle/3Vu1vJavD2RdCT2L6

Regulatory Framework

Regulatory Framework

UAVs are regulated as aircraft by the Federal Aviation Administration (FAA) under 14 Code of Federal Regulations, Part 107, though specific rules are **dictated by the use case**.

- **Commercial use**: “Flying for Work/Business”
  - “Potential for Profit”
  - Requires Remote Pilot Certificate
  - Obtained by passing 60 question exam
  - TSA background check, 16 years of age
- **Recreational use****: “Flying for Fun”
- Clemson Univ. has a Drones Policy
- Liability insurance **required** for Clemson University-owned UAVs
- **FAA Reauthorization of October 2018 is changing the rules regarding recreational use: https://www.faa.gov/uas/recreational_fliers/

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Commercial Use

Examples which are considered Commercial use:

- Paid **and unpaid** photo/videography
- **Data collection**
- Academic **research** project use

Part 107 Operating Rules

- Unmanned aircraft must weigh less than 55 pounds, including payload, at takeoff
- Fly in **Class G** airspace
- Keep the unmanned aircraft within **visual line-of-sight (VLOS)**
- Fly at or **below 400 feet**
- Do not fly **directly over people**
- Do not fly **from a moving vehicle**, unless in a sparsely populated area

Waiver of rules is possible – 90 day minimum wait except in “LAANC” areas

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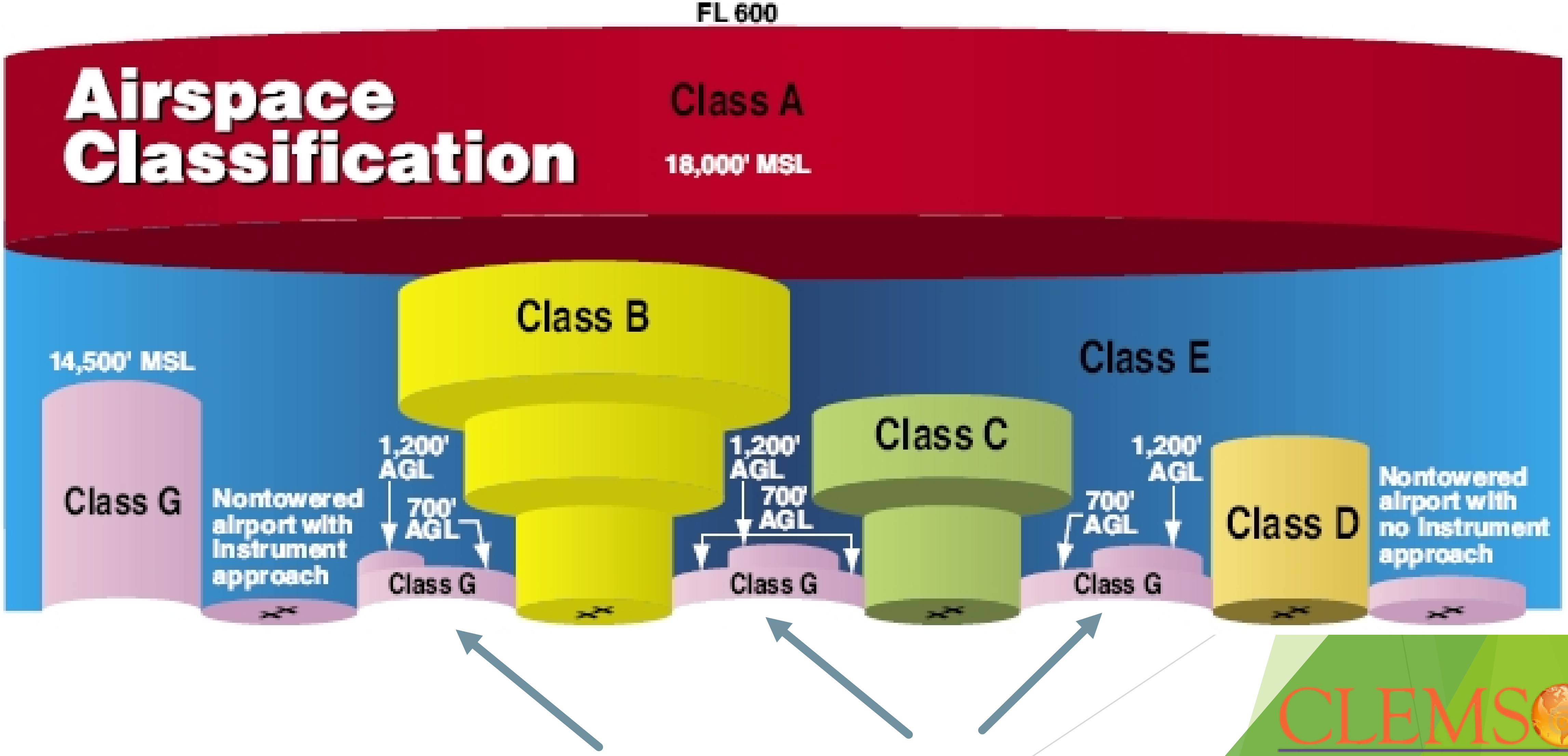
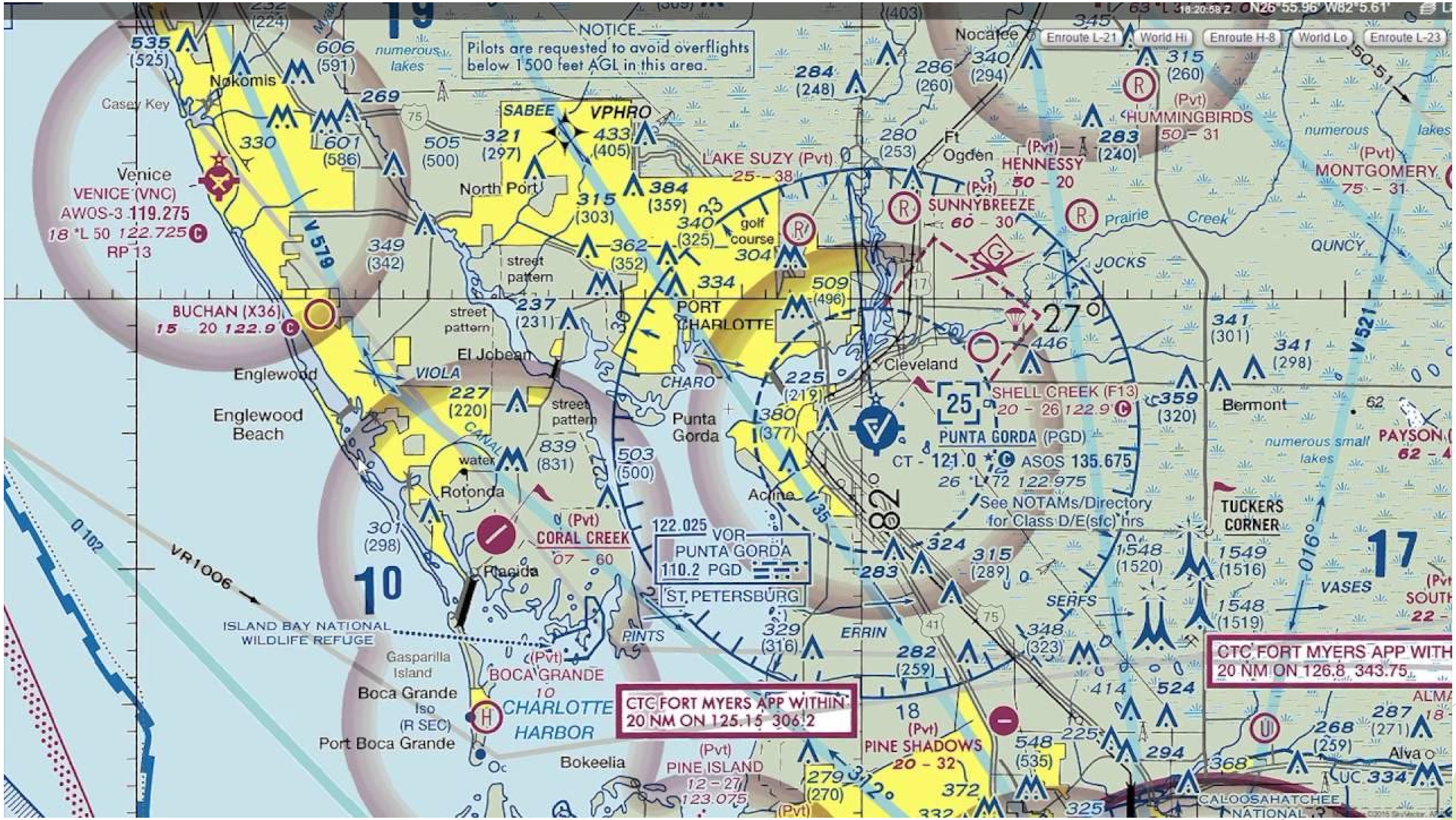
Regulated Airspaces



Sectional Chart



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Example Use Case Scenarios

- **Hobby** use cases**
  - Personal photography and videography
  - Racing drones

- **Hobby** use **used to** fall under Model Aircraft Rules:
  - Register their UAS with the FAA
  - Fly the UAS within visual line-of-sight
  - Do not fly within restricted airspace without authorization
  - Fly UAS that weigh no more than 55 lbs.

- **Instructional** Use: can fall into either category
  - Commercial: Instructor is teaching students to fly as part of academic course
  - Commercial: Collecting data for a research project
  - Hobby: Students flying drones during class to learn another skill, such as gathering aerial imagery

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If in Doubt, Get Certified

Drone Photography Brings $55K FAA Fine to Minnesota Man

Posted by **Betsy Lillian** - June 14, 2016

Google Bookmark | Facebook | Twitter | Print | More

The Federal Aviation Administration (FAA) has reportedly levied a whopping $55,000 fine on a Minnesota man for allegedly flying an unmanned aircraft system (UAS) for a commercial purpose without FAA authorization and in a "careless or reckless manner" last summer.

According to a report from The Daily Signal, 56-year-old Mical Caterina, who does not hold a Section 333 exemption, used a DJI Inspire 1 drone to capture aerial photos of an Aug. 15 ceremony for Cecil the lion in St. Paul, Minn.

Before the flight, the FAA learned that the operations would take place and sent a letter to the event's organizer to detail the differences between model aircraft and UAS, but the agency reportedly did not respond to Caterina's call to go over the details of the flight. After the flight, the FAA did, however, return the call to go over what went down.

The FAA just issued the largest fine ever against a company for flying drones illegally

In October, the FAA proposed a $1.9 million fine, but today announced the fine would only be $200,000.

By April Glaser | @aprilaser | Jan 17, 2017, 2:22pm EST

SHARE

Drew Angerer / Getty Images

The Federal Aviation Administration announced today that it will fine SkyPan International of Chicago, a drone company, $200,000 for conducting 65 illegal drone flights in congested airspace

TRENDING

What would Tim Cook do if he were Mark Zuckerberg? 'I wouldn't be in this situation'.

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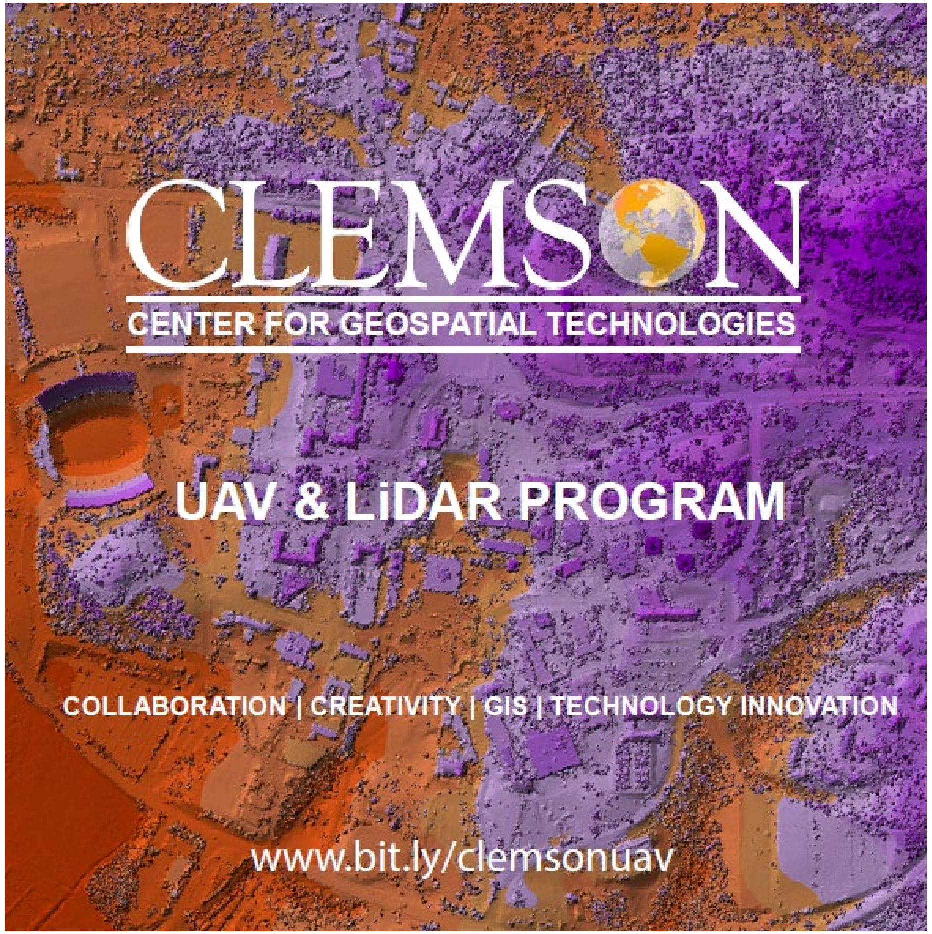
Quiz 3: Regulatory Framework

This is a required quiz you must pass in order to obtain certified hours for our GIS Fundamentals Series.
You can re-take the quiz until you get all the answers right. Must have all answers correct to get a pass on this quiz.

https://forms.gle/rzQz14T9y77STMXo8

Resources Available



UAV and LiDAR Program at CCGT

Integrated services and support for Clemson University in the use of UAVs across many disciplines and applications. Submit request at **bit.ly/clemsonuav**

- Shared equipment resources | FAA certified pilots
- Processing software and workflows | Imagery and geospatial data products
- Training | Teaching curriculum support
- Assistance incorporating resources into grants and proposals

Shared Equipment Resources

CCGT maintains a suite of equipment which is uniquely situated to support research projects and incorporate into grant proposals.

Sensefly eBee+ — Fixed-wing photogrammetric mapping system; Covers up to 500 acres per flight; 60 min flight time; Multispectral and RGB data in single flight

DJI Phantom 4 Pro — Quadcopter UAV with 20 MP camera can capture 4K video

Parrot Bebop 2 — Lightweight quadcopter captures full HD

Faro M70 Laser Scanner — Terrestrial LiDAR scanner creates 3D point clouds with range of 70 m per scan

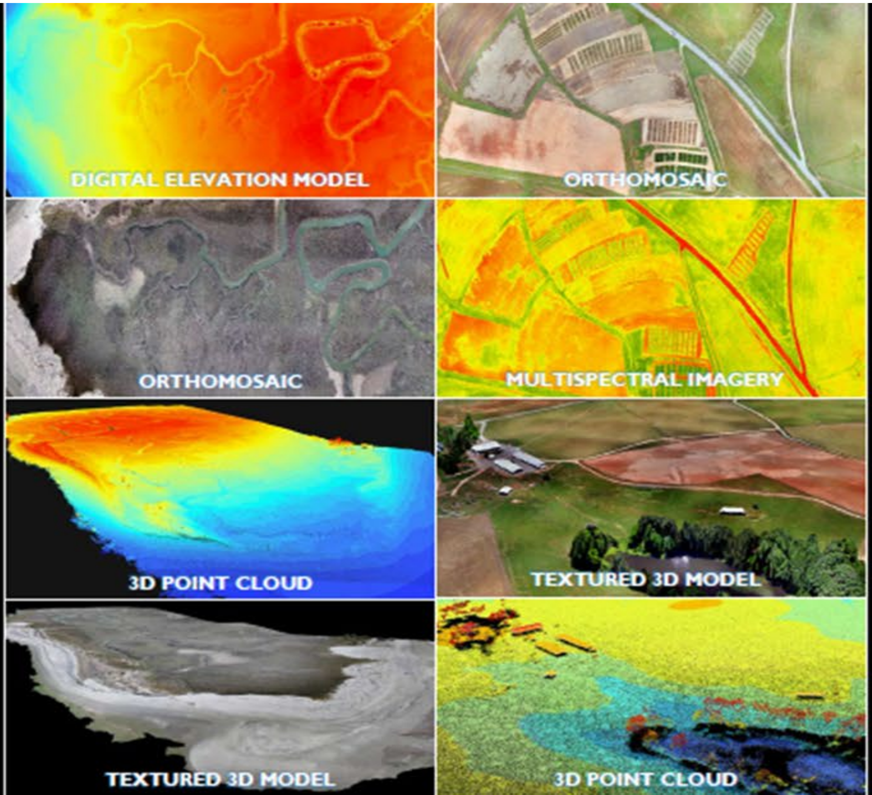
FAA Certified Pilot

Our remote pilot can fly our shared UAVs or your aircraft to ensure compliance with FAA regulations.

Imagery and Geospatial Products

UAVs can be used to deploy sensors to capture up-to-date, high-resolution geospatial datasets, including:

- Aerial orthophotos
- 3D point clouds
- Multi-spectral imagery
- Digital elevation, terrain, and surface models 3D textured surface meshes



Processing Software

We provide software and instructional resources for crunching imagery data from UAVs and LiDAR scans to create new datasets.

Grant Proposal Development

We work directly with researchers to incorporate our UAV and LiDAR equipment and services into grant proposals and to develop collaborative opportunities.

Teaching Curriculum Support

We work with educators to incorporate the safe use of UAVs and LiDAR data collection and processing methods into your lesson plans and student research projects.

Training

We offer workshops to provide end-to-end training on UAV safety and Clemson policies, survey techniques for planning optimal study designs, and processing of the data to transform and leverage data for different use cases.

Applications

Emergency management	Precision agriculture	Historical preservation
Coastal erosion	Infrastructure inspection	Architecture
Highway & transportation	Forest health monitoring	Solar energy assessment

and many more!

www.bit.ly/clemsonuav

Equipment Resources from CCGT

- **LiDAR UAV System**
  - Velodyne puck-based system, 300,000 points/sec
  - Total system accuracy ± 4 cm

- **Hyperspectral UAV System**
  - Headwall near infrared sensor (400-1,000 nm) with 270 spectral bands

- **Mapping and 3D Data Systems**
  - senseFly eBee Plus
    - Fixed-wing, 500 acre coverage per flight
    - RTK GPS functionality RGB and multispectral sensors

  - DJI Phantom 4 Pro: quadcopter with 20 MP camera

  - DJI Phantom RTK: quadcopter with RTK capabilities
  - Parrot Bebop 2: lightweight quadcopter with FPV capabilities

- **Terrestrial LiDAR Scanner**
  - Faro M70 scanner with 70 m range, accuracy ±3 mm

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Important Links and Resources

UAV Services Request Form

bit.ly/clemsonuav

Clemson Drone Policy

https://www.clemson.edu/cusafety/operations/drones.html

FAA UAS Site

https://www.faa.gov/uas/

UAS/UAV use in Education

http://knowbeforeyoufly.org/education-use/

https://www.faa.gov/uas/resources/uas_regulations_policy/media/interpretation-educational-use-of-uas.pdf

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Practical Considerations

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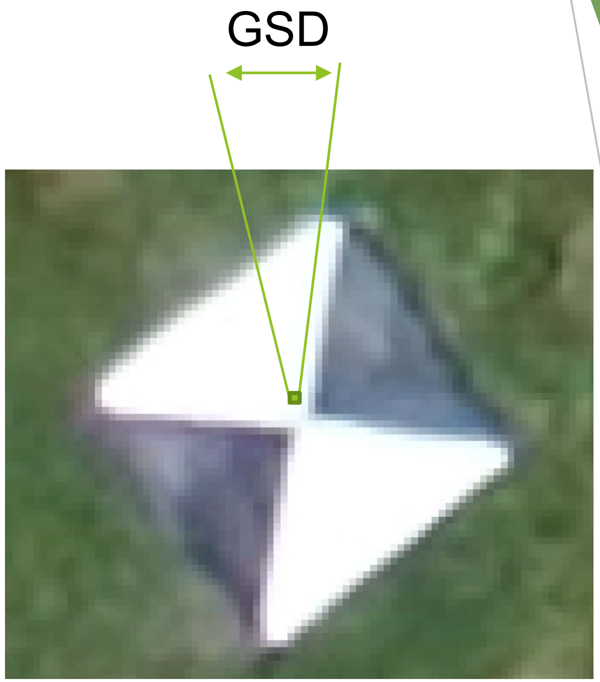
Ground Sampling Distance (GSD)

Area on the ground covered by a single pixel

GSD Calculator		
Sw	14	= the sensor width of the camera (millimeters)
FR	15.4	= the focal length of the camera (millimeters)
H	100	= the flight height (meters)
imW	4608	= the image width (pixels)
imH	3456	= the image height (pixels)
GSD	***1.97***	= Ground Sampling Distance (centimeters/pixel)
Dw	*91*	= width of single image footprint on the ground (meters)
DH	*68*	= height of single image footprint on the ground (meters)



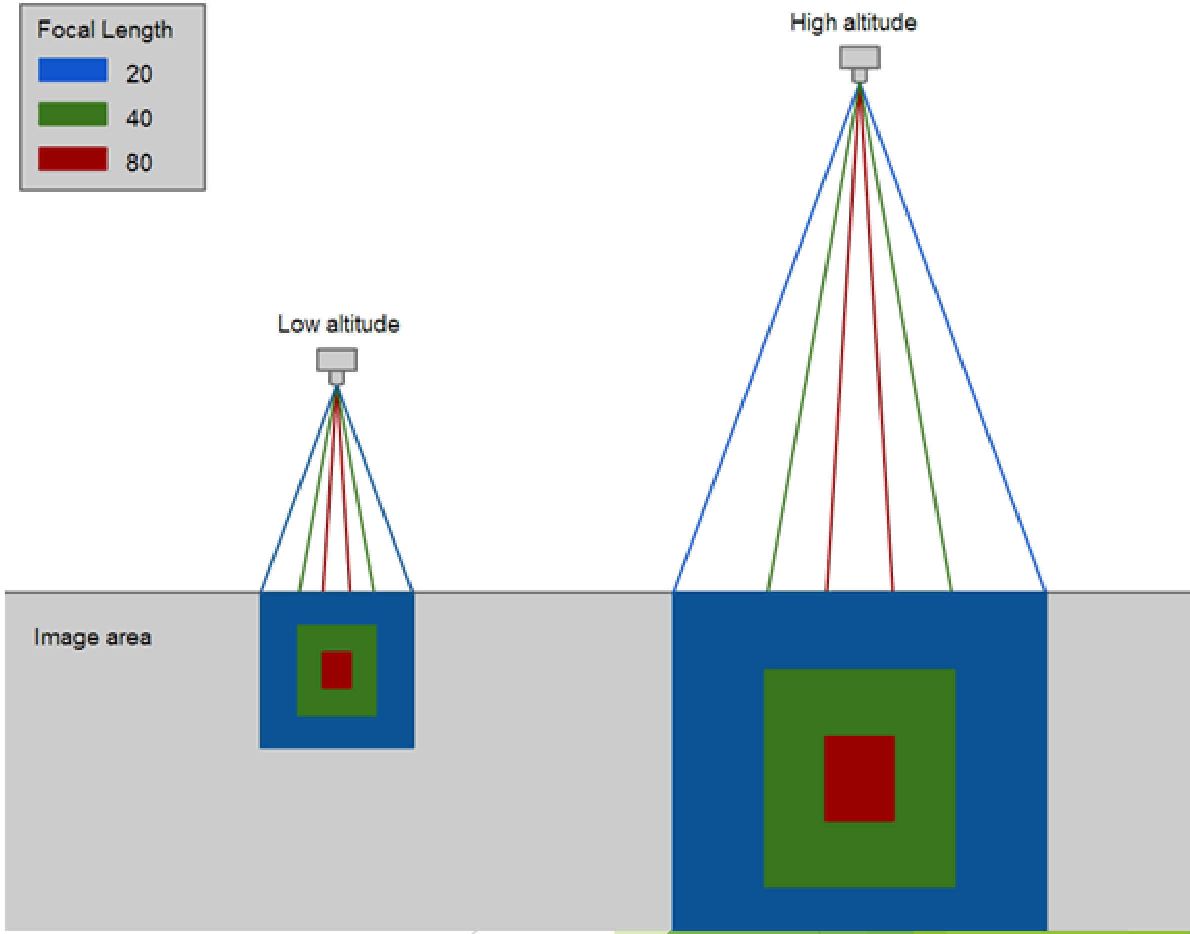
DJI Phantom 4 Pro camera

- Sensor width = 13.2 mm
- Focal length = 8.8 mm
- Image dimensions = 5472 x 3648

Ground Sampling Distance (GSD)

Area on the ground covered by a single pixel

GSD Calculator		
Sw	14	= the sensor width of the camera (millimeters)
FR	15.4	= the focal length of the camera (millimeters)
H	100	= the flight height (meters)
imW	4608	= the image width (pixels)
imH	3456	= the image height (pixels)
GSD	**1.97**	= Ground Sampling Distance (centimeters/pixel)
Dw	91	= width of single image footprint on the ground (meters)
DH	68	= height of single image footprint on the ground (meters)

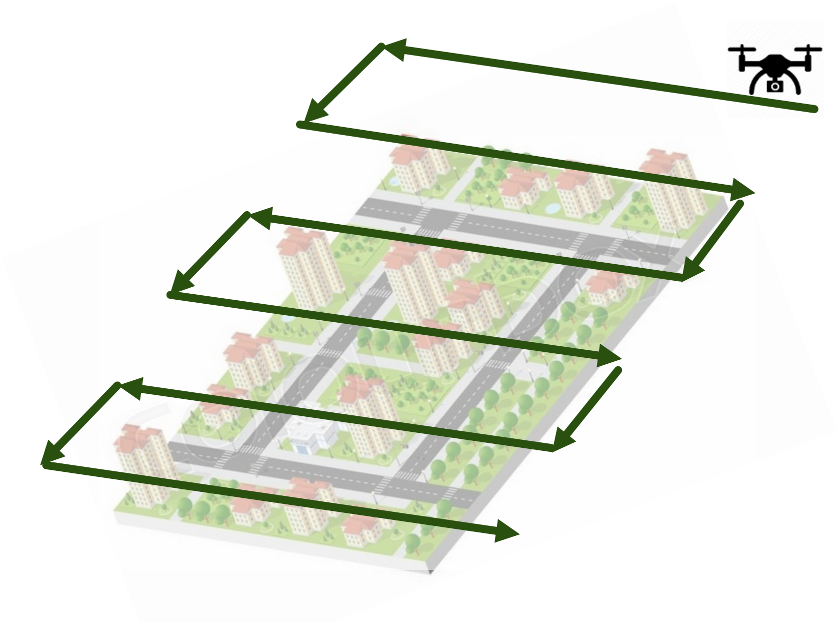


If we **decrease the altitude:**

A smaller area is captured, and therefore the GSD value will decrease: one pixel will capture a smaller area and therefore the image will have **higher spatial resolution**.

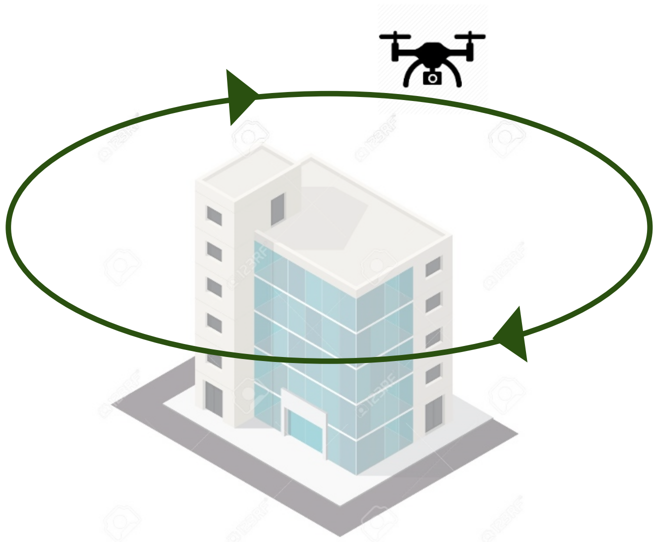
Flight Patterns

Grid



- Downward-facing camera for 2D data
- Inclined camera for 3D data
- Collect multiple directions for more overlap

Orbit



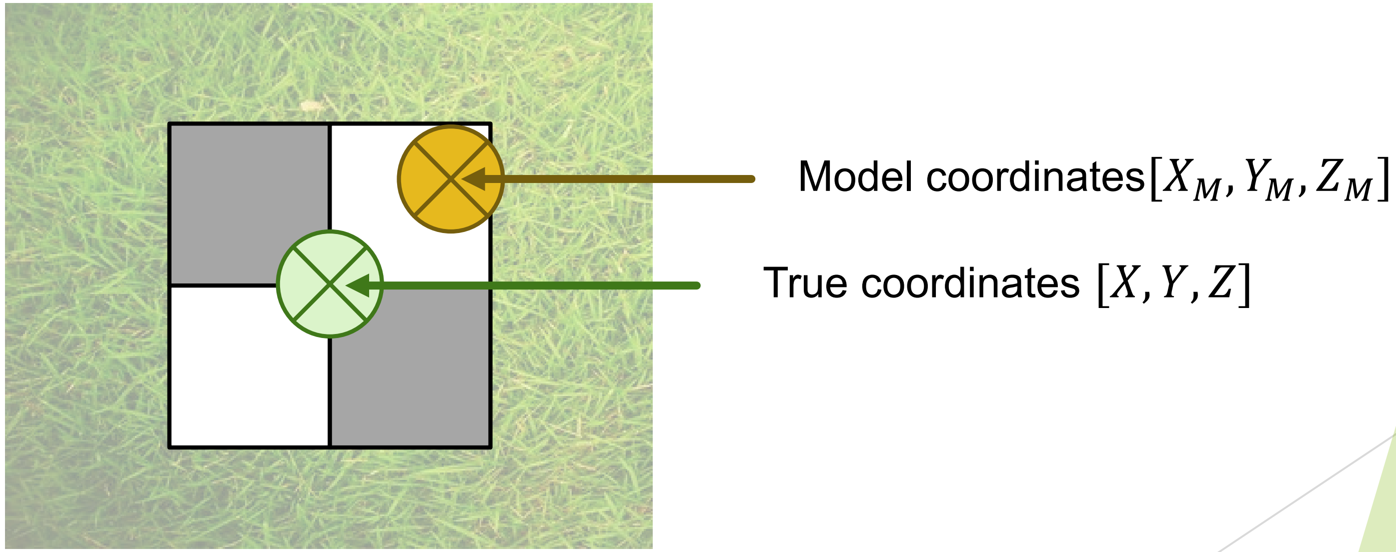
- Central target with clear flight paths
- Multiple altitudes for increased coverage
- 3D data creation

Measuring Spatial Accuracy

Data are geo-located but have errors in position

- Reference data set of higher accuracy used to calculate errors
- Root mean square error (**RMSE**) in Model:

$$RMSE = \sqrt{(X - X_M)^2 + (Y - Y_M)^2 + (Z - Z_M)^2}$$



Measuring Spatial Accuracy

Ground control points (GCPs) used to assess and improve accuracy

- Clearly visible from the air
- Located with high-accuracy GPS or surveyed
- **GCPs** are used to **calibrate** the model during processing
- **Check points** are used to measure **errors**

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Quiz 4: Practical Considerations

This is a required quiz you must pass in order to obtain certified hours for our GIS Fundamentals Series.
You can re-take the quiz until you get all the answers right. Must have all answers correct to get a pass on this quiz.

https://forms.gle/sDu2hJG4MRxPtLpj9

Setting Up a Flight

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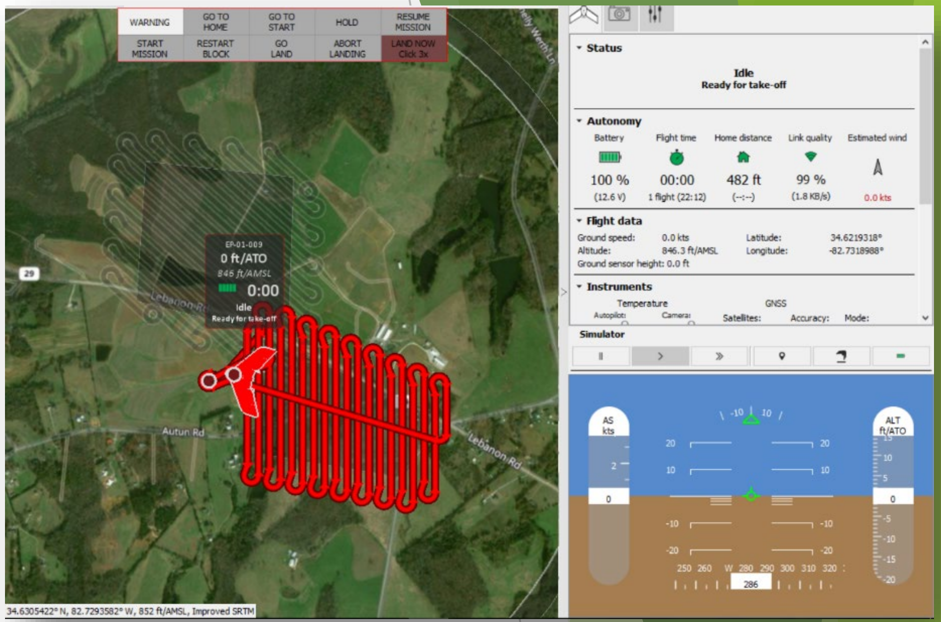
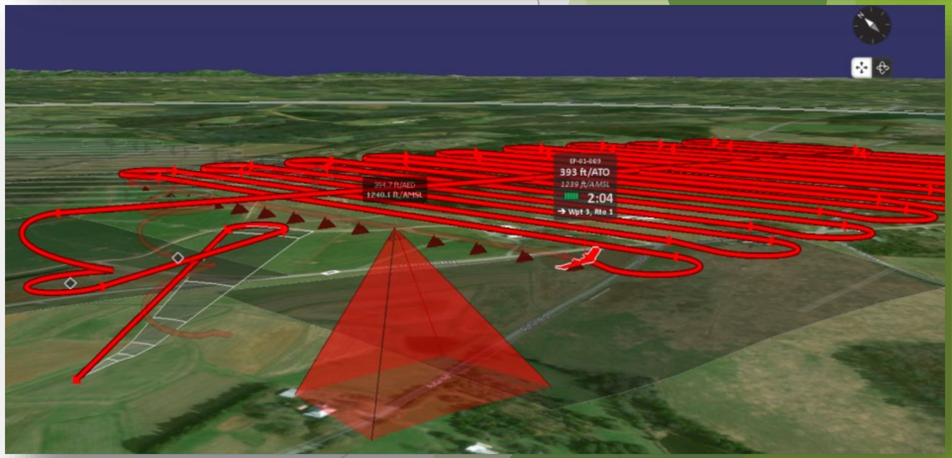
Basic Field Procedures

To get photos for creating spatial data:

- Perform site recon and ensure Part 107 rules can be met
- Area of interest and flight parameters are set
- Targets laid out prior to flight and locations surveyed
- Drone follows pre-programmed route using GPS
- Series of pictures are taken with high overlap
  - Nadir (straight down) for 2D imagery
  - Inclined for better 3D reconstruction
- Photos are processed using software to create resulting datasets





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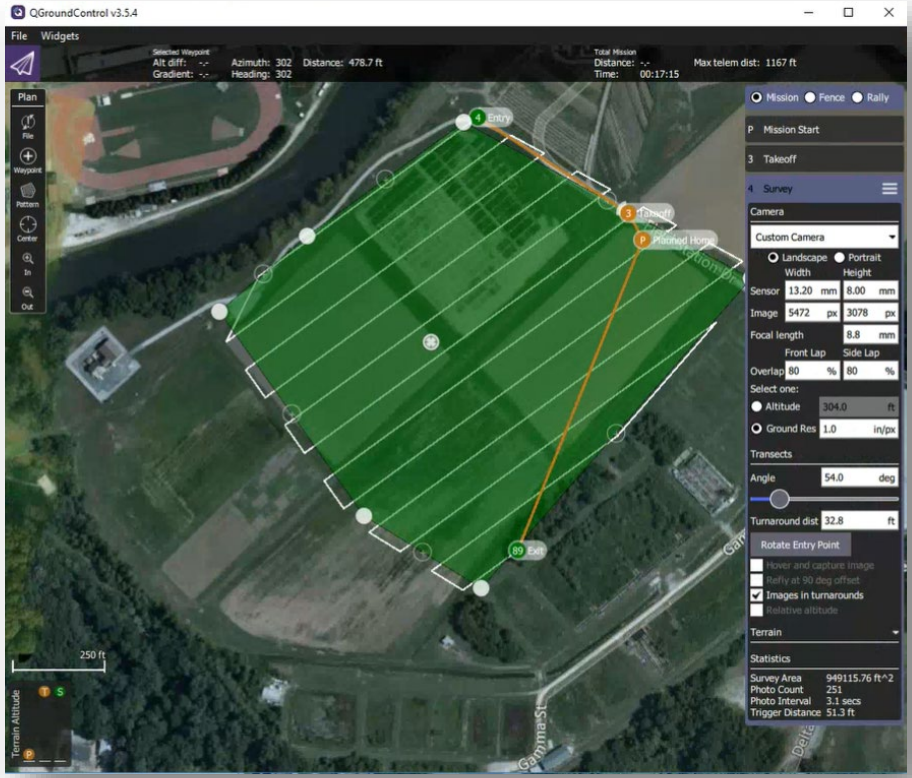
Setting Up a Mapping Flight

Using QGroundControl, create a simple grid flight

- Manually set camera parameters
- Specify overlap
- Set up mission grid
- DJI Phantom 4 Pro camera
  - Sensor width = 13.2 mm
  - Sensor height = 8.0 mm
  - Focal length = 8.8 mm
  - Image dimensions = 5472 x 3648



Hands-On: Drone Flight

Drone Flight: Observe a demo mapping flight outside of Cooper Library

https://vimeo.com/242999590

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Hands-on: Processing Photos from a UAV

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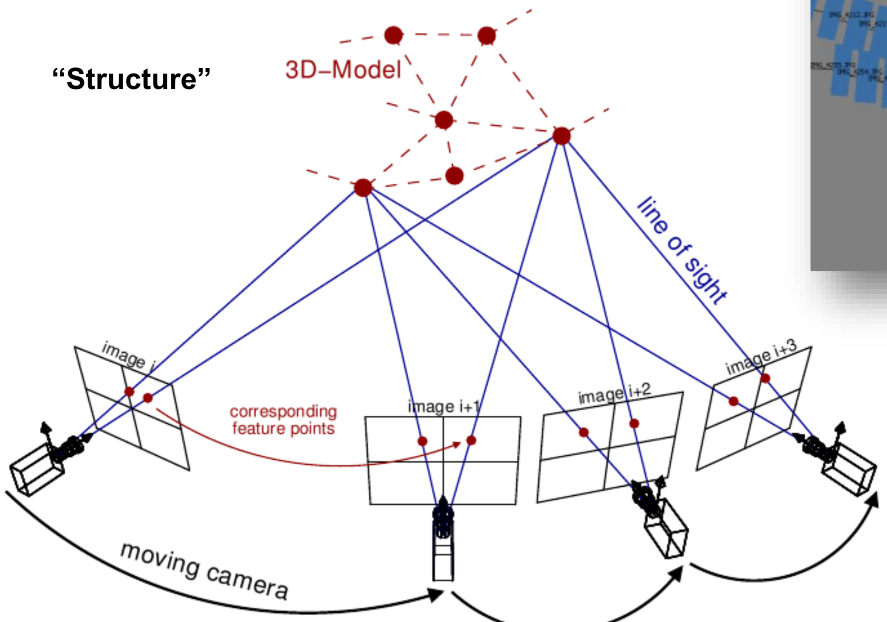
Processing Photos from a UAV

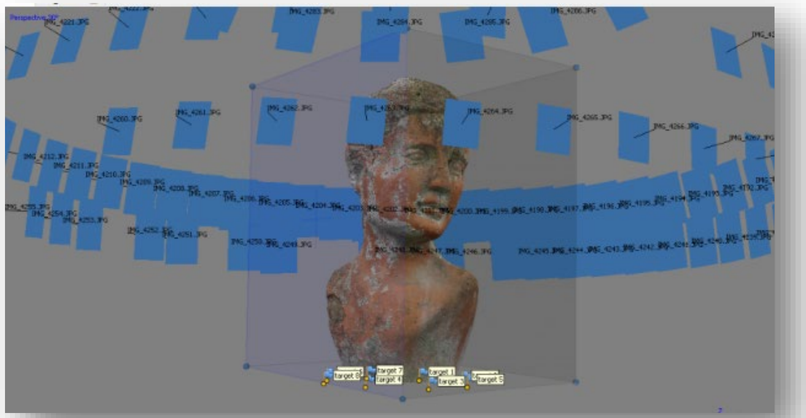
Processing software uses **Structure from Motion (SfM)** algorithms to transform overlapping 2D photos into 3D data

- Sensor (camera), computer, and software are all that are needed
- Photos taken from many locations, orientations

“Structure”

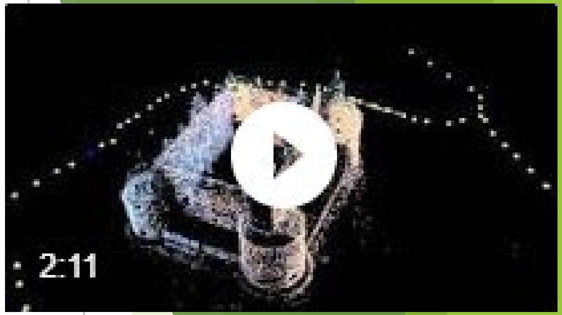


“Motion”



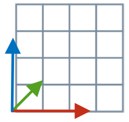
Structure from Motion Processing

- Software identifies unique **key points** in photos
- Matches **tie points** between photos
- Analyzing key point movement gives orientation, location of **cameras** (photos) and **3D structure**
- Incorporate **ground control** to optimize camera parameters and locations

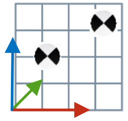


https://www.youtube.com/watch?v=i7ierVkXYa8

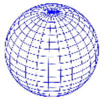
Model in pixel coordinate space →



Identify georeferenced targets and/or camera locations →



Model georeferenced to real-world coordinate system



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Software Options

Product	Single License	Subscription	Cloud Processing
Drone2Map	N/A	$250/year 5 users (academic) $2,500/year 5 users (administrative)	Yes
Pix4D Mapper	$4,990 $1,990 (academic)	$350/mo	Yes
Agisoft Metashape Pro	$3,499 $550 (academic)		Yes
Drone Deploy	N/A	$89/mo (single, limited features) $449/mo (single, full featured) Enterprise available	Yes
OpenDroneMap	Free*	N/A	Yes

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Hands-On: Create Data from Photos

- Process our photos of the Seneca Bottoms into geospatial data
  - 3D point cloud
  - Digital elevation model (DEM)
  - Imagery mosaic
  - 3D mesh
- Determine georeferencing accuracy
- Improve model accuracy
- Export data to analyze in other software

- Flight used Sensefly eBee + flown at 350 ft, 75% overlap

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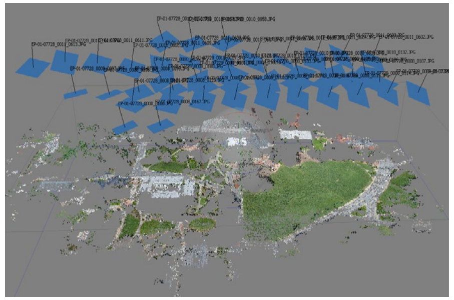
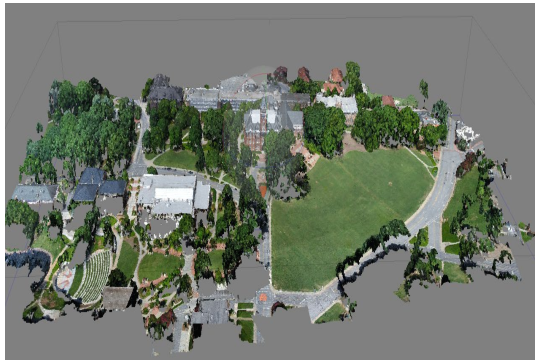
Structure from Motion Workflow

The general processing workflow for SfM software is

Use photos to estimate camera locations, build a low density point cloud



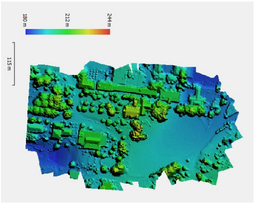
Generate high-density point cloud



Incorporate ground control points

Build a georeferenced mesh and texture

Convert to a Digital Elevation model



Orthorectify and export Orthomosaic

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Certification

- For those of you wanting to get certificate hours for this workshop, follow these steps:
  - Watch the videos for each section
  - Complete the quizzes for sections: (you can attempt as many times as you need to)
    - 1. Introduction to UAVs
    - 2. Commonly Used Sensors
    - 3. Regulatory Framework
    - 5. Practical Considerations
  - Complete the hands-on tutorial on section 7.2 and send the pdf report from Agisoft to our UAV and LiDAR specialist, Maziar (mfoolad@clemson.edu).

Thank You!

Please provide your feedback at

Bit.ly/ccgtfeedback

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