Mapping with UAV's

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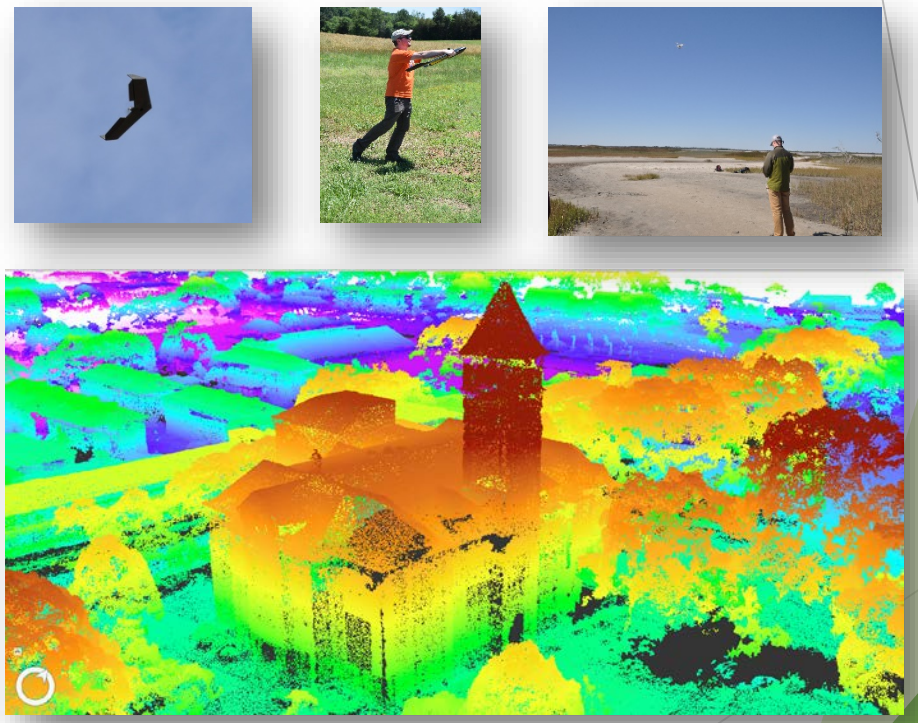

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Outline

Introduction to UAVs

- What is a UAV?
- Commonly Used Sensors
- Applications and Examples of Geospatial Data

Regulatory Framework

Hands-On Activities

- Structure from Motion (SfM) Processing Photos to 3D Data

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Presentation and Data

The presentation slides can be found on the CCGT drive:

- Open the Windows Explorer 
- Right-click on **This PC** > **Map network drive…**
- Folder: \\group.clemson.edu\group\Apps\CCGT
- Click **Finish**
- Navigate to Workshops
- Copy the UAVs_Forestry folder to your Documents folder

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What can you see?

Scale = 1:500
Scale (inset) = 1:40

Resolution = 15 cm/pix

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What can you see?

Scale = 1:500
Scale (inset) = 1:40

Resolution = 8 **mm**/pix

Folly Island, SC
March 25, 2017

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What can you see?

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Resolution = 15 cm/pix

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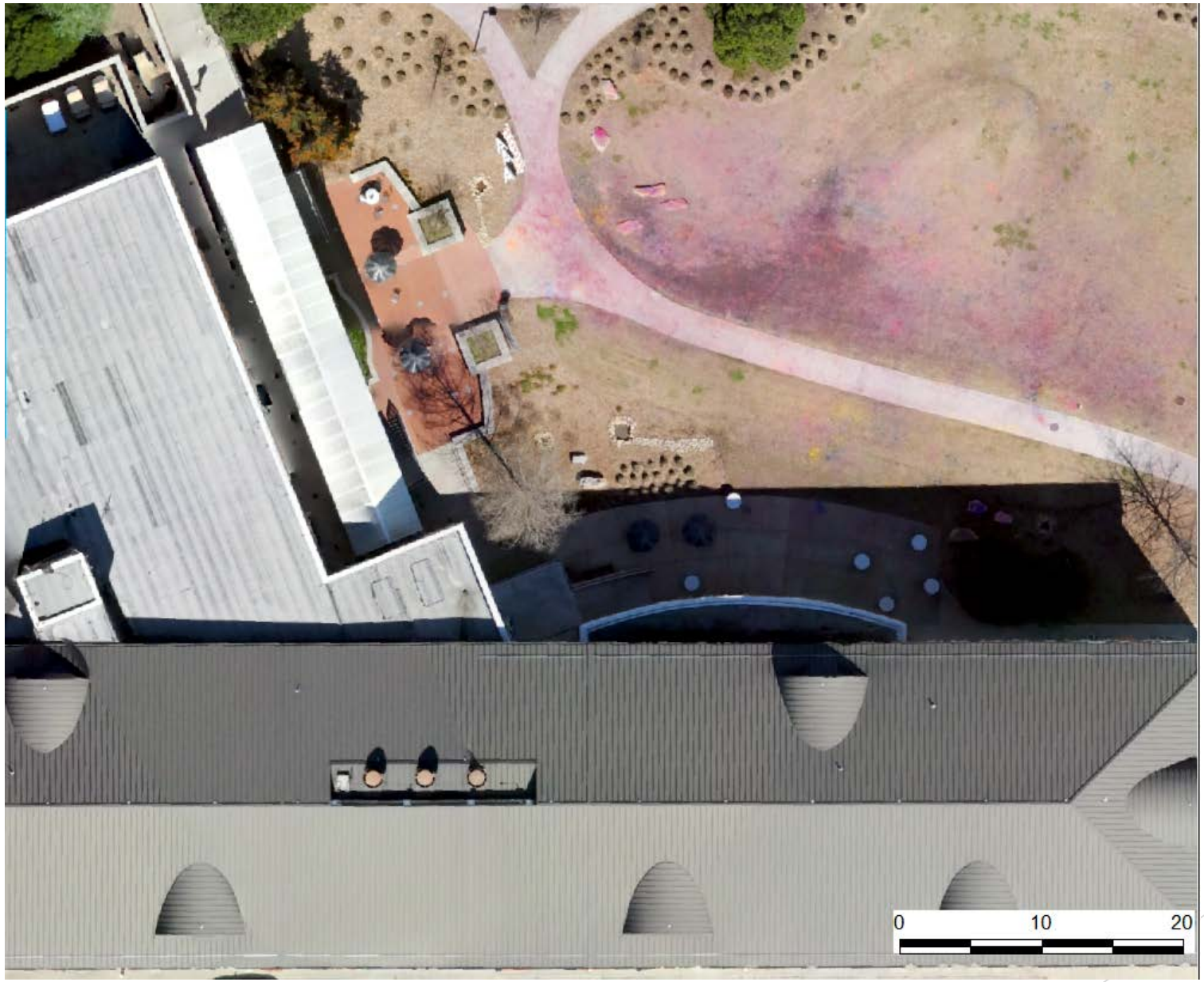
What can you see?



Scale = 1:300
Resolution = 2.5 cm/pix

Hendrix Student Center
March 4, 2018

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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 System (sUAS)
    - Weight of 0.55 – 55 lb

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Industry Forecast

- The economic value of drones is predicted to reach **$82 billion** and create over **100,000 jobs** by the year 2025.
- 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.

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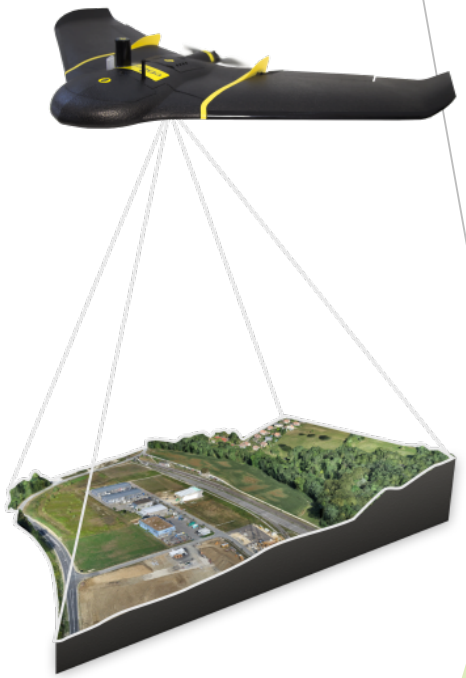
UAV as Data Collection Platform

- 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 data products
- Coverage of areas between conventional aerial photography and on-the-ground surveying
  - Up to ~500 acres in a flight with fixed-wing UAV



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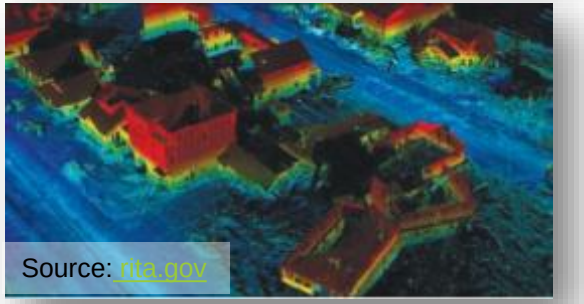
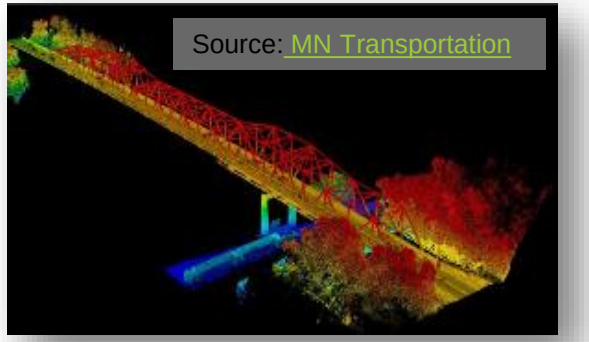
Applications of UAVs – a "Short List"





- 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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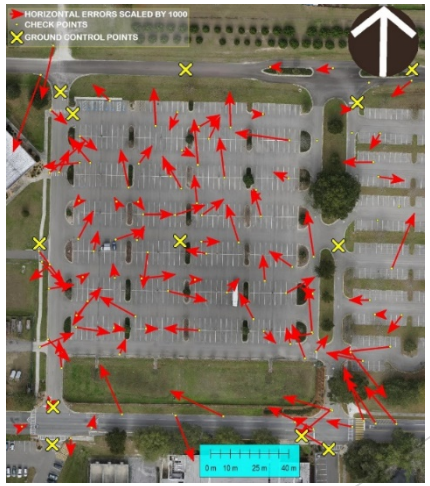
Positioning and Autopilots

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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Common Sensors RGB Camera

The most common sensor is the digital RGB camera

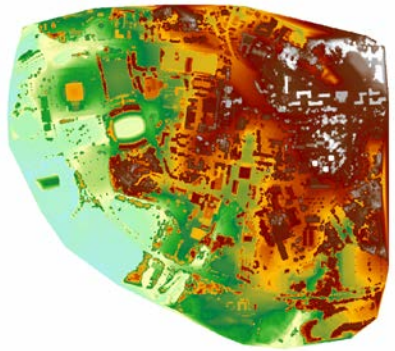
- Takes photos/video in visible spectrum.
- Images used directly or photogrammetrically processed to create geospatial data
- Many UAV cameras for photography are suitable for mapping
- Need intervalometer or software trigger

Common Sensors RGB Camera

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

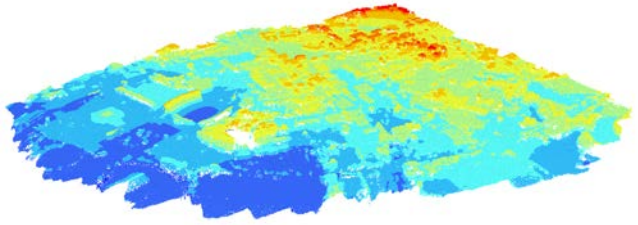
Still Images and Video

True-color Orthomosaics



Digital Elevation Model

3D Textured Meshes



Point Clouds

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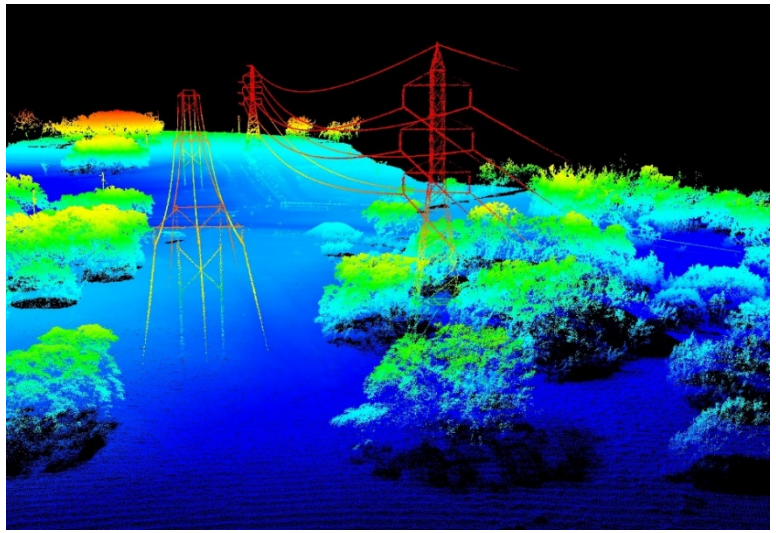
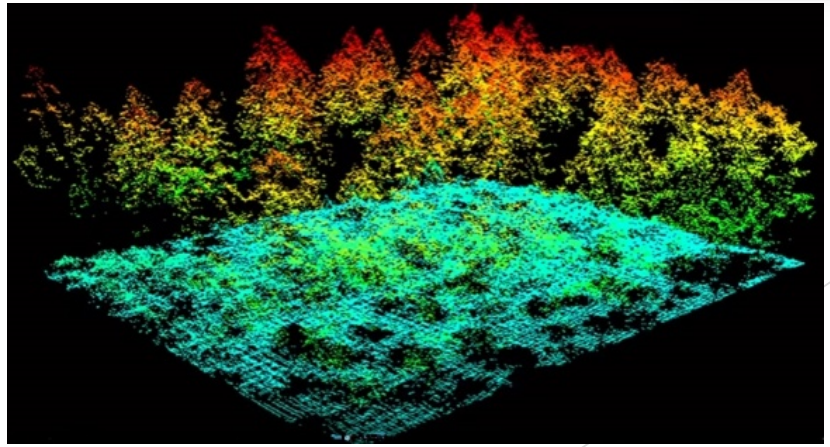
Common Sensors LiDAR Scanner

- **Li**ght **D**etection **A**nd **R**anging
- Active remote sensing system which emits laser pulses for rangefinding
- 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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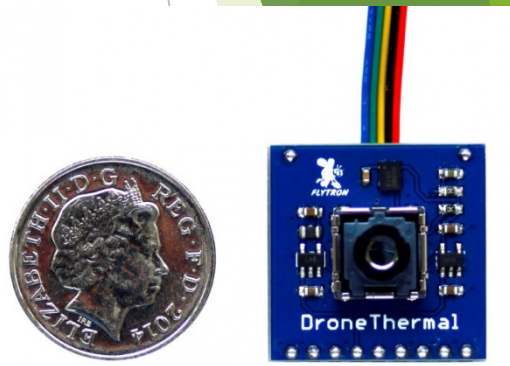
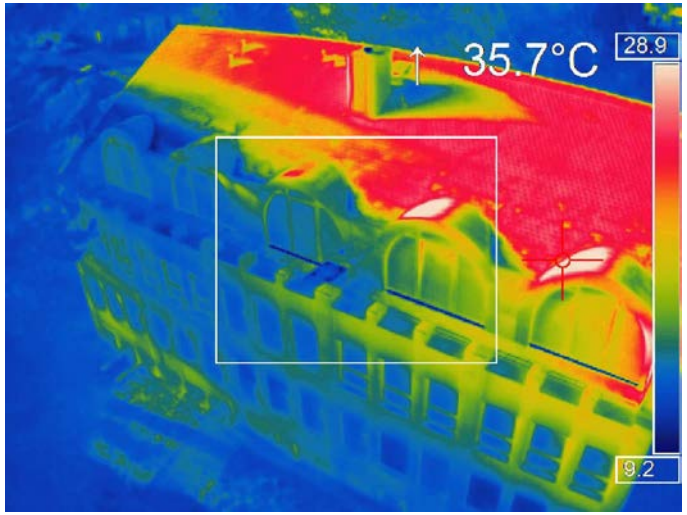
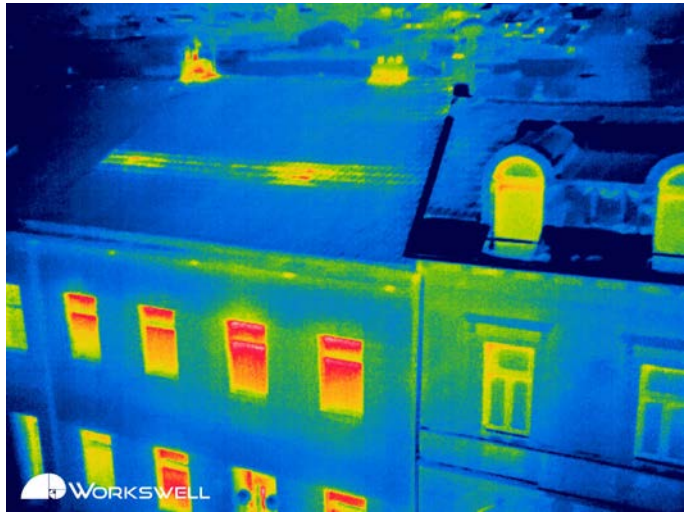
UAV Sensors: Thermal Camera

- 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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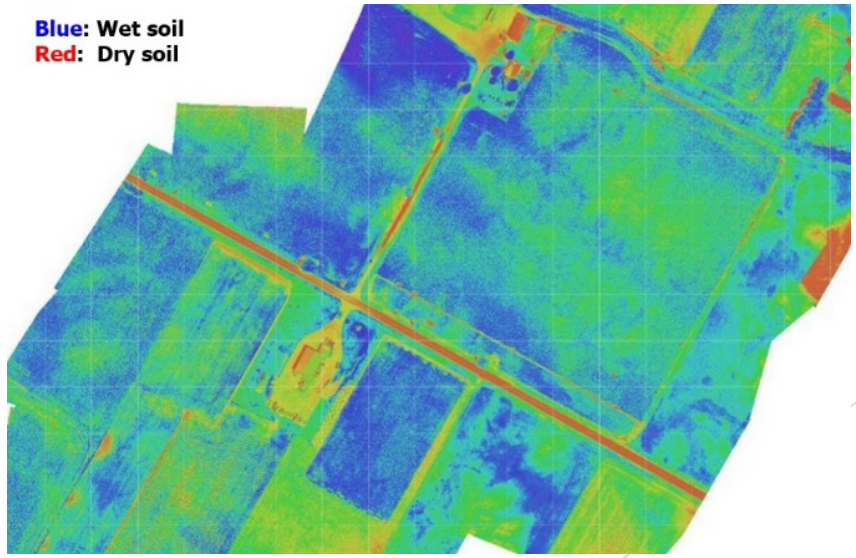
UAV Sensors: Thermal Camera

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)

Near Infrared (790 nm)

Green (550 nm)

Red (660 nm)

Red Edge (735 nm)

RGB Sensor

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UAV Sensors: Multispectral Camera

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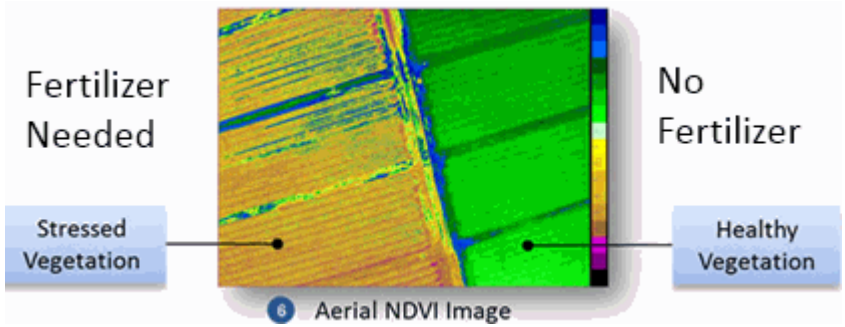

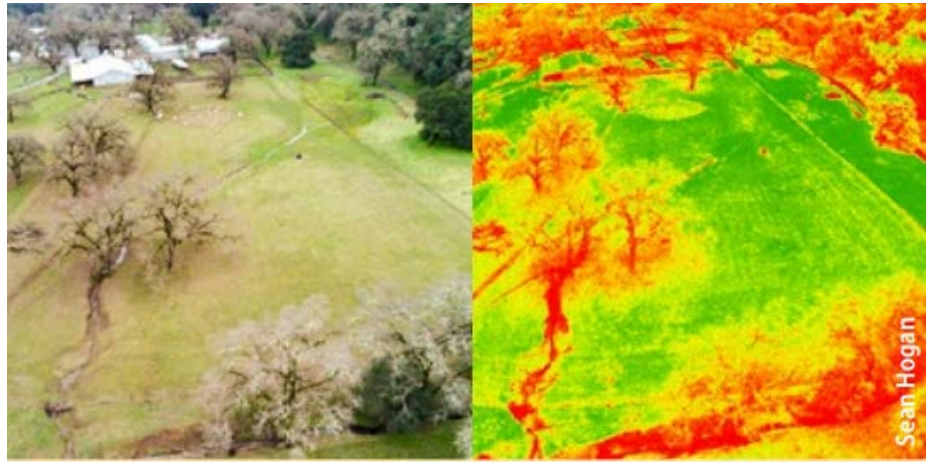

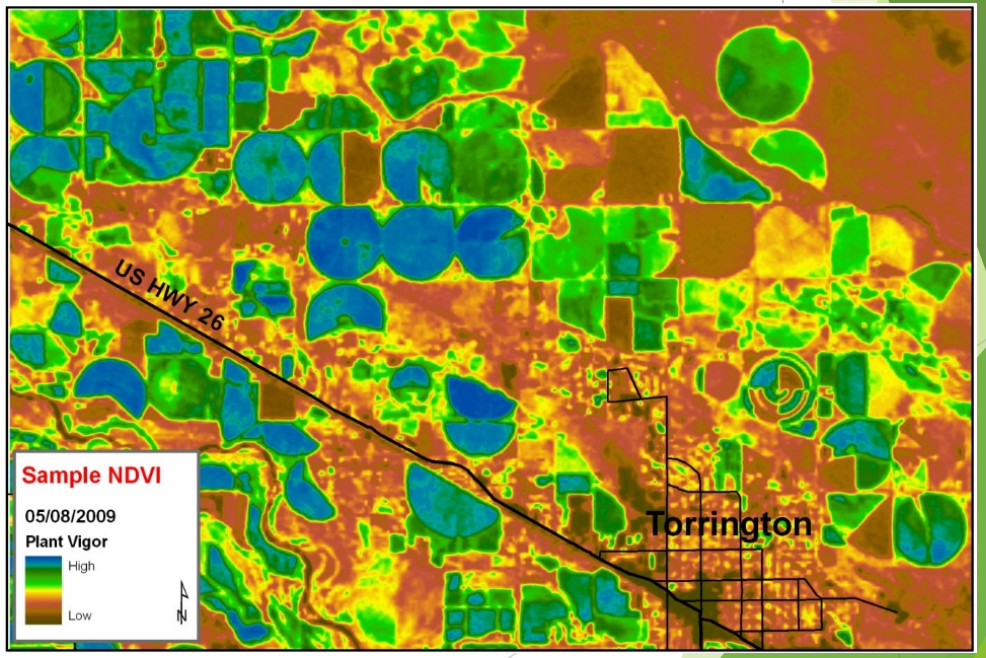

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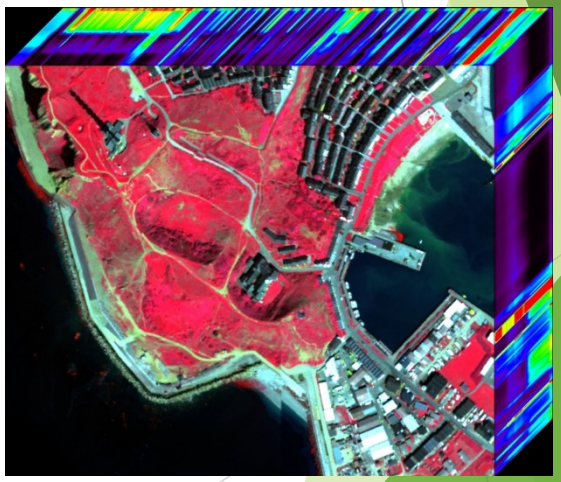
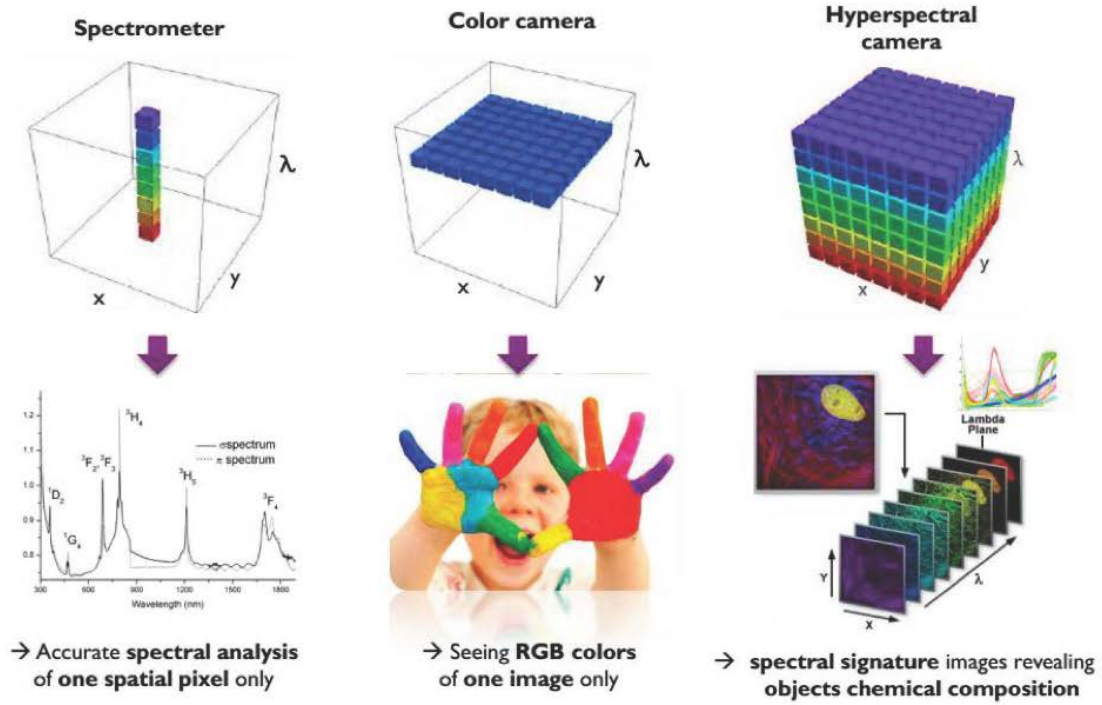
UAV Sensors: Hyperspectral Sensor

- 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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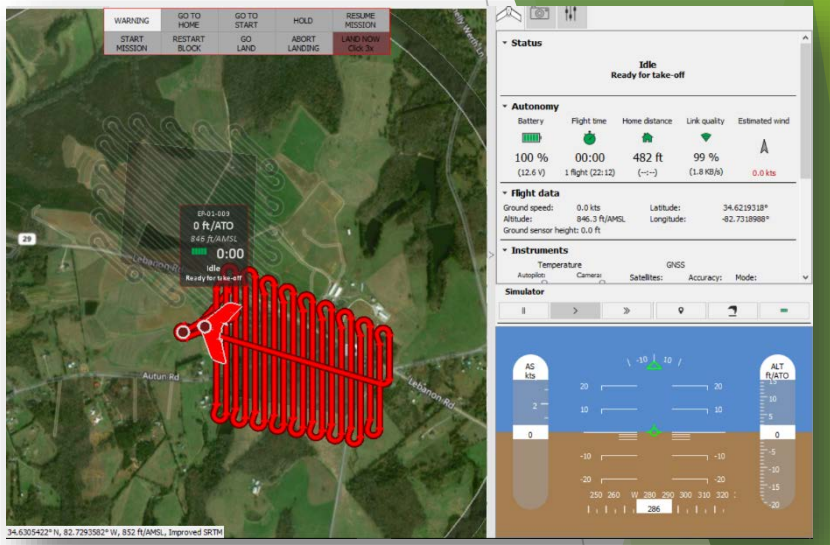
A UAV Mapping Flight

https://vimeo.com/242999590

To get photos for creating imagery, point clouds, DEMs:

- Area of interest and flight parameters are set in software
- Targets laid out prior to flight and locations surveyed
- UAV uses GPS to follow pre-programmed route
- 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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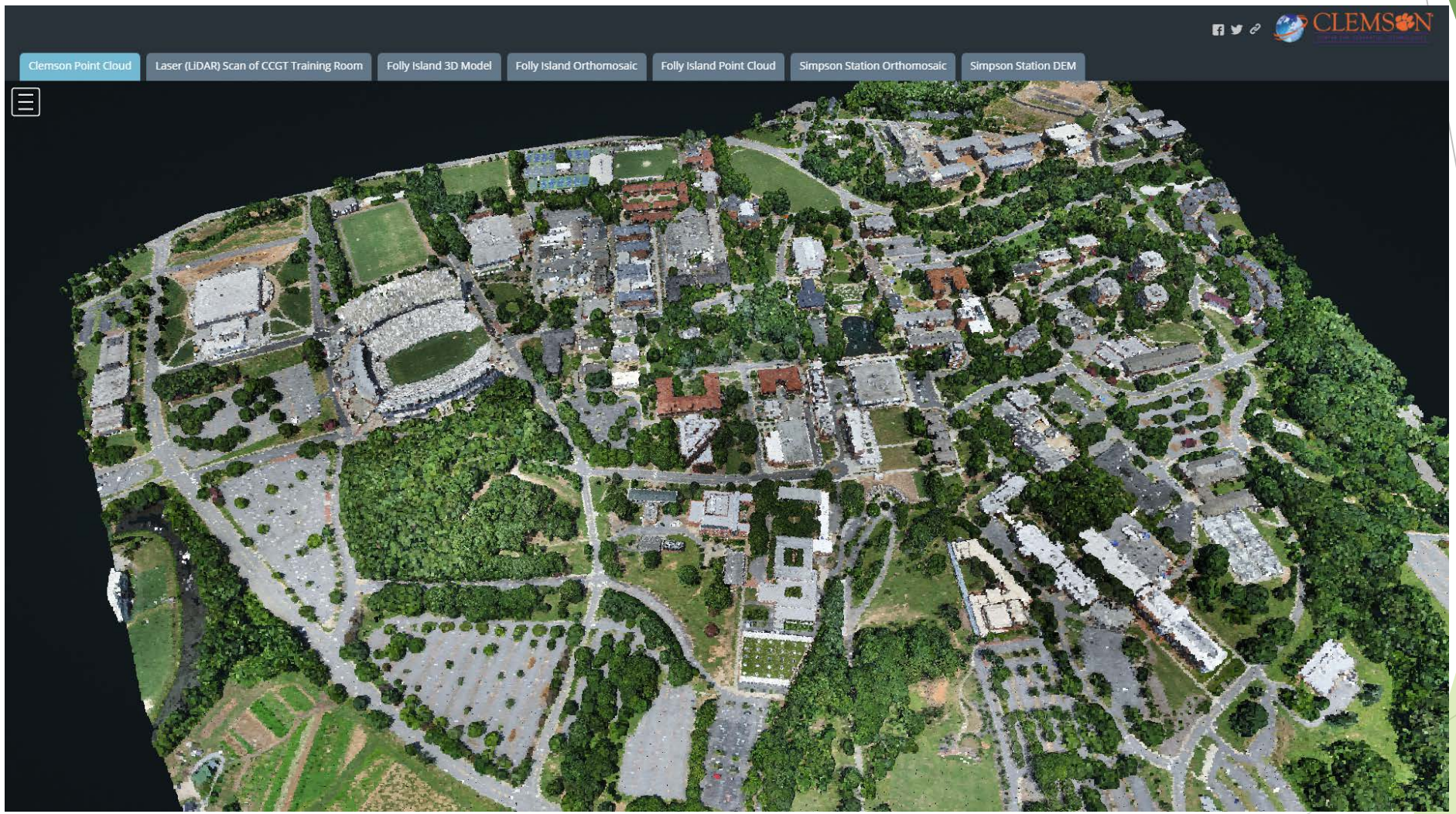
Examples of Data Products



https://arcg.is/Cajzi

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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

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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
  - Fly at or below 400 feet
  - Fly during daylight
  - 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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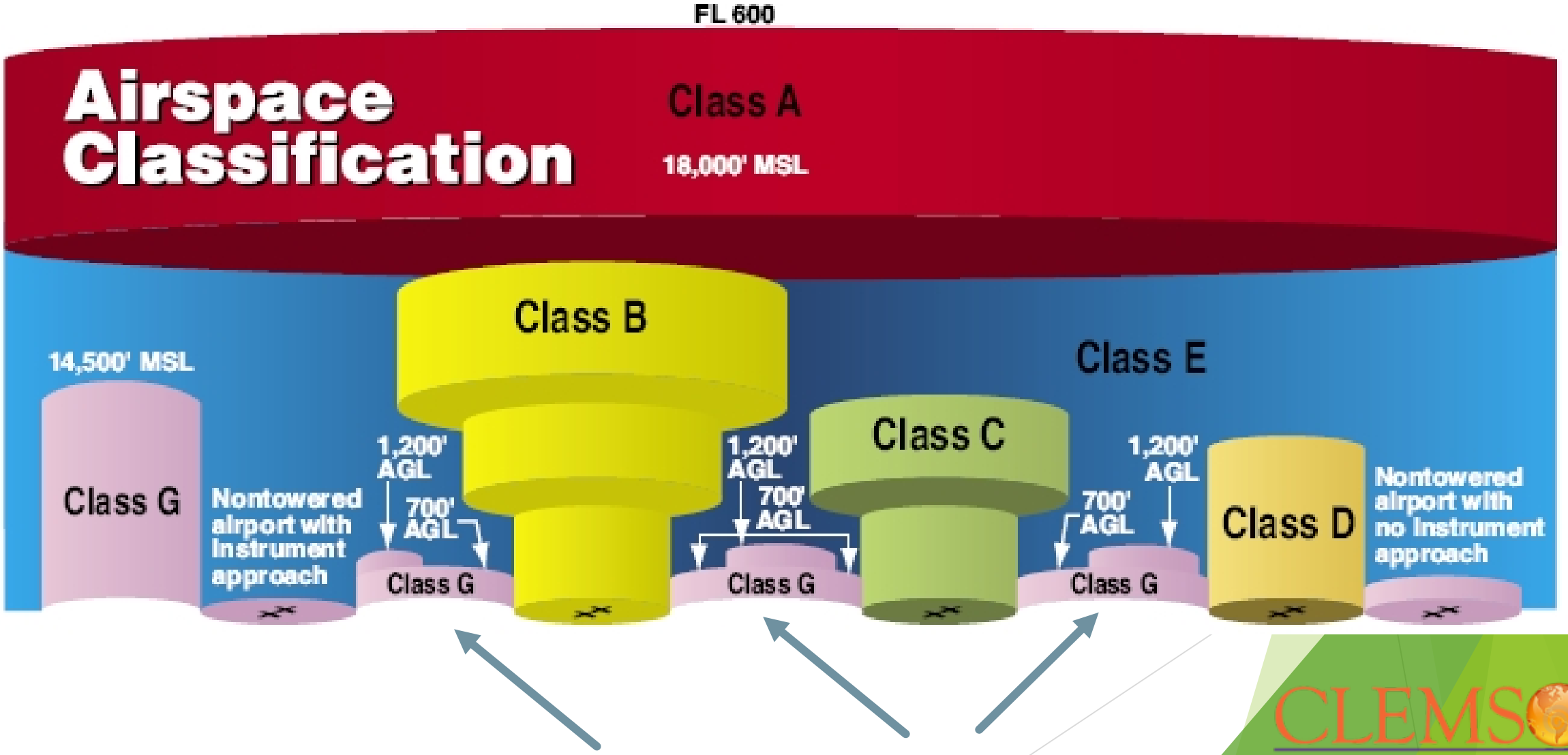
Regulated Airspaces



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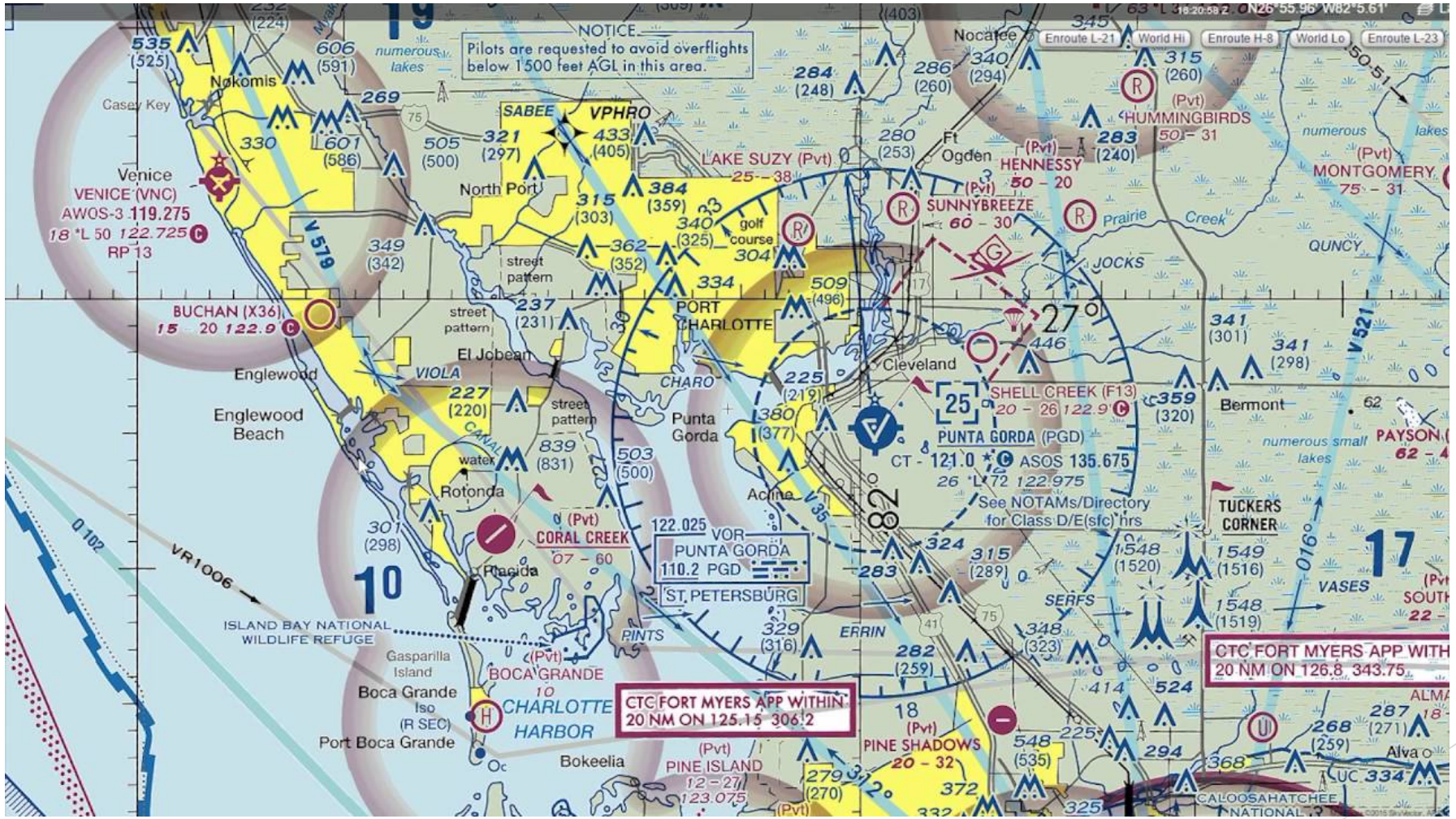
Sectional Chart



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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
  - Provide prior notification to the airport and air traffic control tower, if one is present, when flying within 5 miles of an airport
  - 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

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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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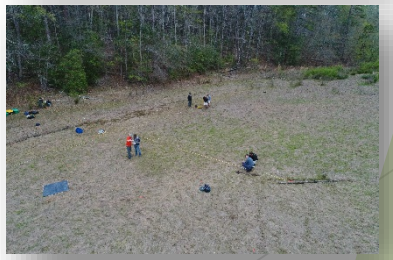
UAV and LiDAR Program at CCGT

Integrated services and support for Clemson University in the use of UAVs and LiDAR across many disciplines and applications.

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

- Submit request at www.bit.ly/clemsonuav



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Equipment Resources from CCGT

Equipment includes a variety of UAVs, sensors, and laser scanner

- Sensefly eBee Plus
  - Fixed wing capable of 500 acre coverage per flight
  - 60 min flight time
  - RTK GPS functionality can be enabled
  - RGB and multispectral sensors available
- DJI Phantom 4 Pro
  - Quadcopter UAV with 20 MP camera
  - 25 min flight time
- Parrot Bebop 2
  - Lightweight quadcopter with full HD capabilities
- Faro M70 Laser Sanner
  - Terrestrial LiDAR scanner creates 3D point clouds with 70 m range per scan
- Upcoming: LiDAR UAV and hyperspectral-equipped UAV

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Important Links and Resources

CCGT Request Form

www.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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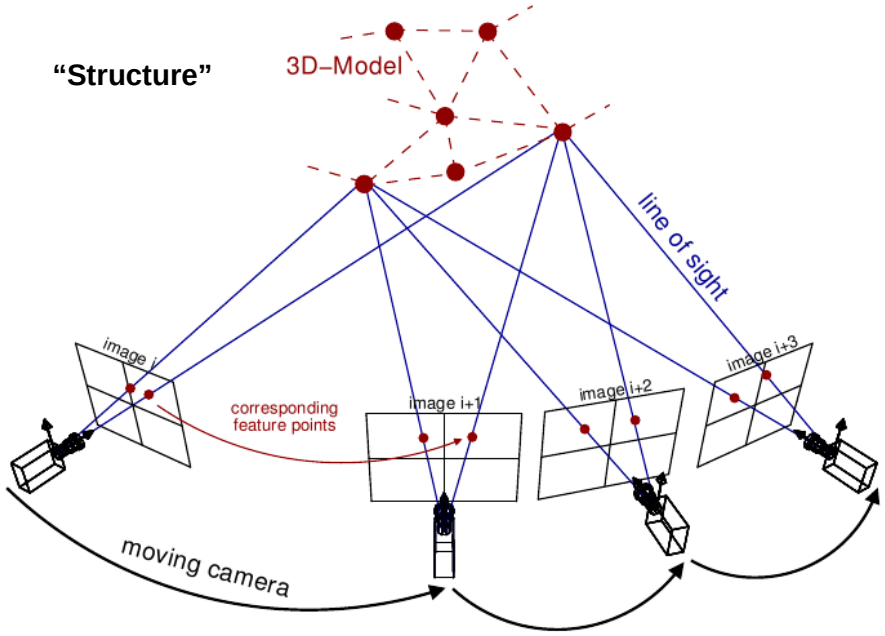
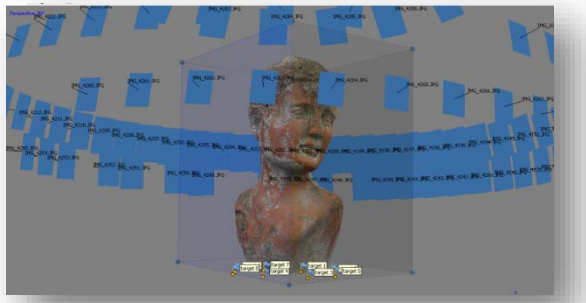
Processing Photos from a UAV

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
- Cost generally lower than LiDAR with comparable density and accuracy





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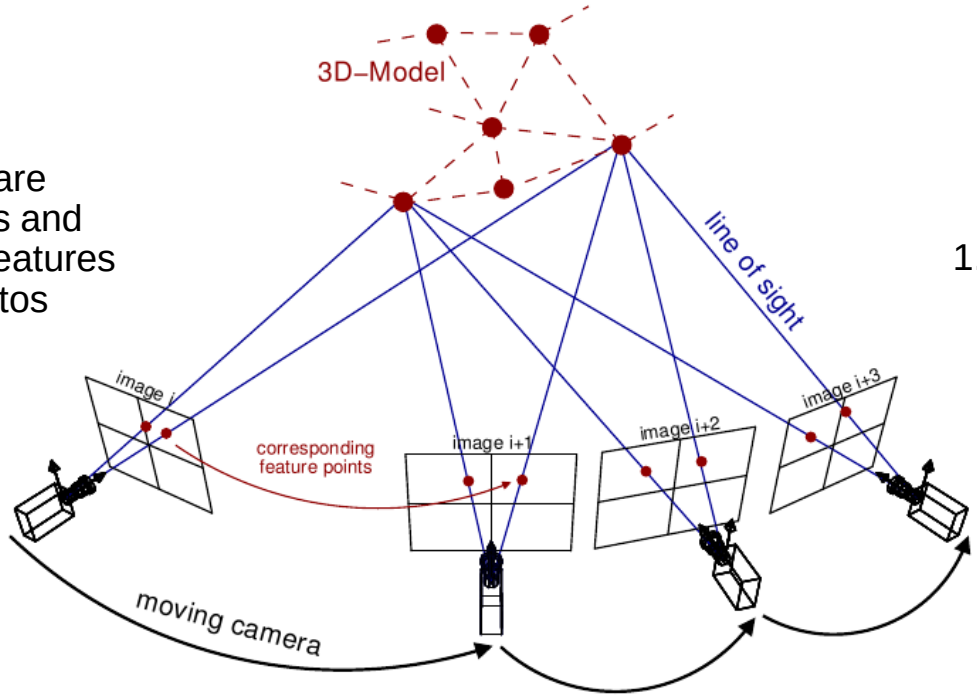
Structure from Motion Processing

Software identifies and matches features in photos

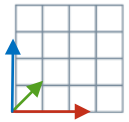


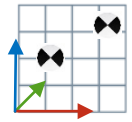
Photos taken with high overlap

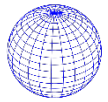
Fits and outputs models of

1. Camera locations, parameters
2. 3D orientation of features

Model in pixel coordinate space → Identify georeferenced targets and/or camera locations → Model georeferenced to real-world coordinate system







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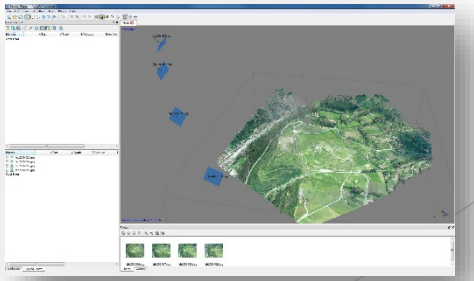
Structure from Motion Platforms and Software

Because any camera can be used, there are many effective platforms for capturing photos

- Single Person
  - Handheld digital camera, tripod, pole, etc.
- Balloons and kites
  - Inexpensive, generally simple, not subject to FAA regulations

- UAV/UAS
  - Able to cover moderately sized areas
  - Pre-programmable flight patterns
  - GPS integrated into many systems

- Software
  - Agisoft PhotoScan Professional ($550 academic license)
  - Pix4D Mapper ($3,500 annual license)
  - Other commercial offerings (DroneDeploy…)
  - Open-source: Bundler, CMVS + PMVS, SFMToolkit



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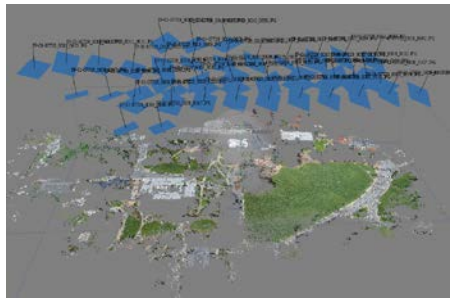
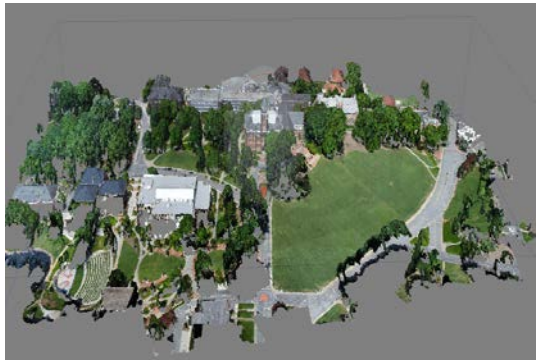
Structure from Motion Workflow

The general processing workflow for SfM software is

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



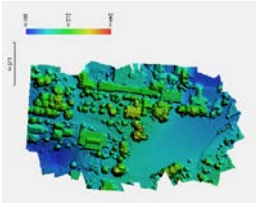
Generate high-density point cloud



Incorporate ground control points

Build a georeferenced mesh and texture

Convert to a Digital Elevation model



Orthorectify and export Orthomosaic

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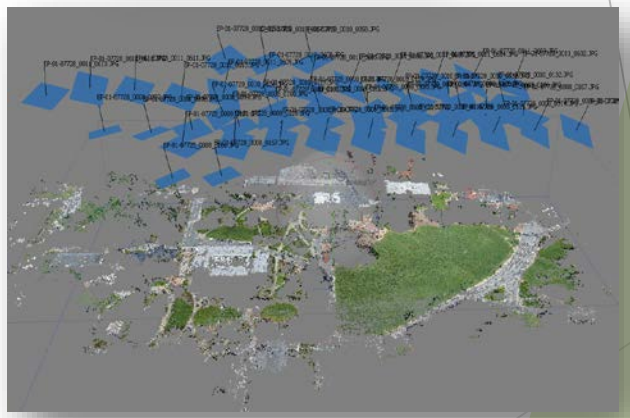
Hands-On: Turn Photos into Map Data

We will process photos captured with a UAV into several data sets

Example data were acquired with a Sensefly eBee+ and S.O.D.A. camera

- Drone flew at 390 ft above ground
- Ground sampling distance of ~1.1 inch/pixel
- 70% overlap in photos



Also – process photos from Hunnicutt Creek/Kite Hill area

- DJI Phantom 4 Pro – 180 ft above ground
- Ground sampling distance of ~0.7 inch/pixel
- 80% overlap in photos

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Tutorial Link

The tutorial instructions are located at
www.bit.ly/clemsongis

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