UAV and Ground-Based Remote Sensing Technologies

Kendall DeJonge, USDA-ARS, Fort Collins CO

Southern Rocky Mountain Agricultural Conference and Trade Fair

February 7, 2018
Monte Vista, CO

Water Management and Systems Research Unit

Fort Collins, CO

United States Department of Agriculture
Agricultural Research Service

Innovations in Irrigation Water Management since 1911

What we will cover today:

- Definitions
- Training and regulations
- Multi-rotor vs. fixed wing
- Our UAVs
- Controls and software
- Resolution vs. altitude
- Example images collected
- Ground-based remote sensing and ET research

What the heck do you call it?

- **UAV/UA-Unmanned Aerial Vehicle/Unmanned Aircraft** – a vehicle that is capable of propelling itself through an airspace w/o a human pilot on board
- **Drone-Dynamic Remotely Operated Navigation Equipment** – a UAV capable of purposeful movement autonomously.
- **UAS-Unmanned aircraft system** – "an unmanned aircraft and the equipment necessary for the safe and efficient operation of that aircraft." (FAA.gov)
- **sUAS-Small Unmanned Aircraft System** – a UAS in which the UAV weighs less than 55 pounds, including everything that is onboard or otherwise attached
- Controlled autonomously by computers or under the remote control of a pilot on the ground (manual)
- UAS-include (UA, unmanned aircraft, control system (GCS), control link, other related support equipment required as per the application)

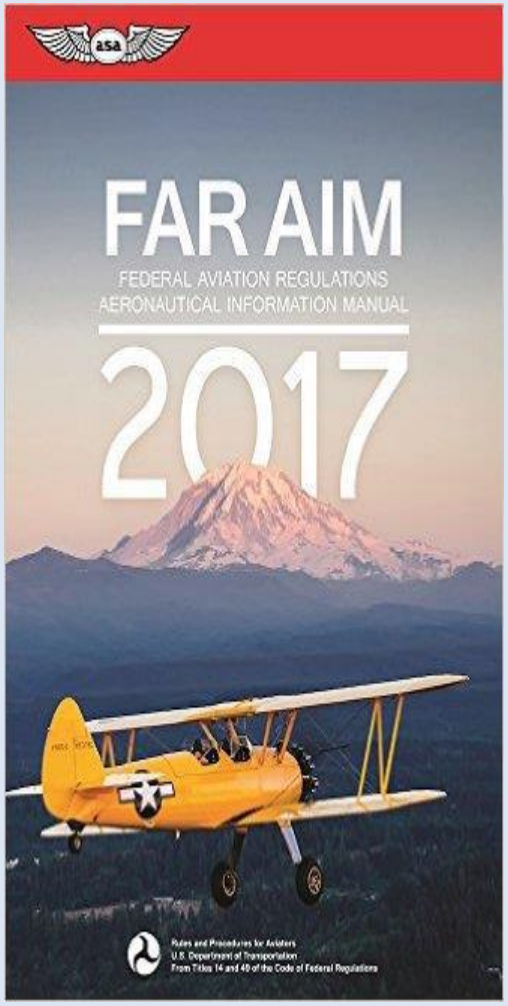
What training is required?

- A Remote Pilot Certificate for operating a UAS is required unless flying as a hobby or under a current Section 333 grant of exemption.
  - UAS use for hobby – “pursuit outside one’s regular occupation engaged in especially for relaxation” (FAA.gov)
- Pilot Requirements
  - Must be at least 16 years old
  - Pass initial aeronautical knowledge test at FAA-approved knowledge testing center
  - Must be vetted by the Transportation Safety Administration (TSA)

FAA sUAS rule (14 CFR part 107)

FAA sUAS rule (14 CFR part 107)

- Aircraft Requirements
  - 55 pounds or less – includes weight of sensors and batteries
  - Each vehicle must be registered with FAA
  - Preflight inspect aircraft before missions
- Operating Rules (Rules are subject to waiver)
  - Operate in G airspace
  - Must stay within operator's line of sight
  - Cannot fly over 400 feet
  - Must fly during day
  - Must fly at or below 100mph
  - Must yield right of way to manned aircraft
  - Must NOT fly over people or from a moving vehicle



Multi-Rotor UAVs

<u>Advantages</u> of multi-rotor vs. fix-wing

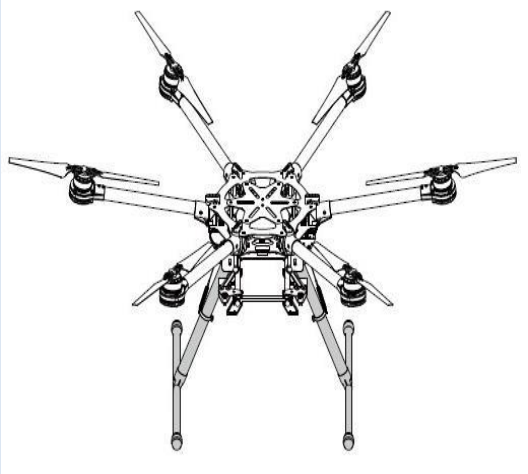
- Ability to hover and perform precise agile maneuvering
  - Obstacle collision avoidance
- Vertical takeoff and landing
  - Shorter onsite setup time
  - Smaller area required for approach and landing
  - Less damage due to “belly landings”
- Takeoff and Landing direction not dependent on wind direction
- Barriers to entrance
  - Lower initial cost of equipment
  - Less training time

Multi-Rotor UAVs

<u>Disadvantages</u> of multi-rotor vs. fix-wing

- Endurance and speed
- Large area coverage
- Payload transport efficiency
- System complexity and maintenance costs
- Electric motors only
- Doesn’t glide in the event of power failure
- Flights in bad weather

Multi-Rotor UAS



General Components of a Multi-Rotor UAS

- Frame
  - Aircraft Frame
  - Motor/Propellers/ESC
- Battery
- Flight Controller
  - Communications – Telemetry(Data Transmission & Autonomous Control)/RC Receiver (Receives signal from RC Controller)
  - Flight Sensors – GPS/Barometer/Compass
- Ground Control Station(s)
- Payload (Not Required)

DJI Phantom 4

- Quadcopter
- Diagonal Size (Propellers Excluded) ~13.8in
- Weight (Battery & Propellers Included) ~3lbs
- Horizontal Speed ~45mph
- Max Endurance 28min
- Recommended Max Wind Speed ~22mph
- Operating Temp. 32° to 104°F
- Live video feed transmitted to controlling tablet/smartphone
- Total Cost ~$1,199.00

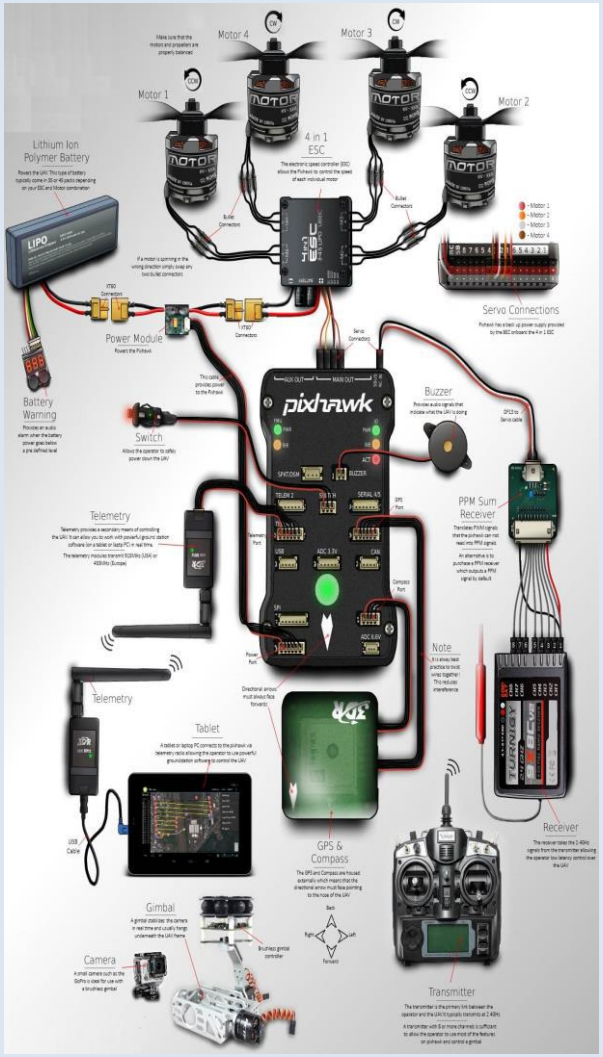
DJI Spreading Wings S900

- Hexacopter
- Diagonal Size (Propellers Excluded) ~35.4in
- Total Weight (Battery and Payload Excluded) ~7.3lbs
- Payload Weight ~7.7lbs
- Flight Time ~15 min. (12000mAh & 15lbs)
- Horizontal Speed ~35mph
- Recommended Max Wind Speed ~10mph
- Operating Temp. 14° to 104°F
- 10000~15000mAh, 6S LiPo Battery
- Cost ~$1,199.00 (Frame only)
  - Battery Cost $499.99

DJI Spreading Wings S1000

- Octocopter
- Diagonal Size (Propellers Excluded) ~41.1in
- Total Weight (Battery and Payload Excluded) ~9.7lbs
- Horizontal Speed ~35mph
- Flight Time ~18 min. (15000mAh & 21lbs Takeoff weight)
- Payload Weight ~11.0lbs
- Recommended Max Wind Speed ~18mph
- Operating Temp. 14° to 104°F
- 10000-20000mAh, 6S LiPo Battery
- Cost $1,499.00 (Frame Only)
  - Battery Cost $339.99

Flight Controller



The Flight Controller utilizes information from flight sensors and user inputs, and send recommended signal to control each of the motors. With a GPS and Ground Station the Flight Controller can give the UA Autonomous flight capabilities.

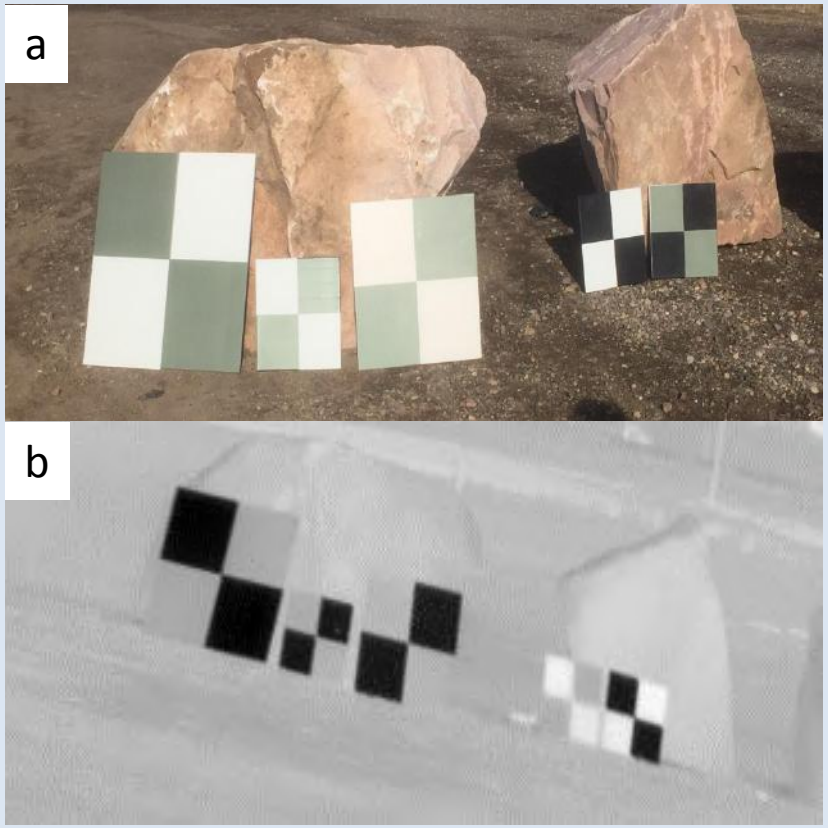
- DJI A2 – Flight controller designed for application on DJI models
  - Limited customobility
  - Cost $539.00
- PixHawk – Open source flight controller
  - High customobility
  - Cost ~$200.00
  - Requires more knowledge for setup

Image software

		Pix4D Mapper Pro	Icaros OneButton
Cost	Monthly	$350	
	Annually	$3,500	$1,200(Basic) $2,995(Pro)
	Perpetual	$8,700	$2,995(Basic) $7,995(Pro)
Included Autopilot Software		Tablet Application which exports data to cloud storage for processing in Pix4D Mapper	Computer based software (Purchased separately) which uses tablet/smartphone to transmit commands (transmitting app only available for android devices)
Limitations		Doesn't work well with Multispectral images w/ more than 3 bands	Software hasn't been tested with thermal images Basic version doesn't include tools to fine tune output

Ground control point

- Used to geo-reference images and insure images are at the correct scale
- Targets can be made of different materials, as long as they are visible to the camera and easily distinguishable from other material in the image
  - Card board
  - Tarps (plastic and cloth)
  - CD
  - Tile
- The dimensions and GPS location of each targets are of known and recorded
- For best results a minimum of 5 points should be used (one in the middle and in each corner)



Flight Planning

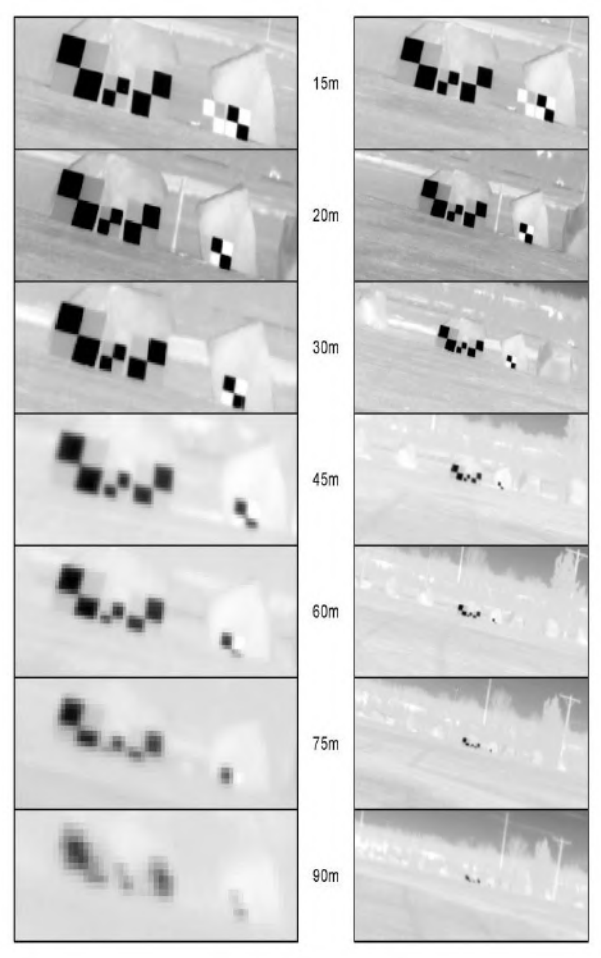
Choosing a flight altitude

- Based on field size and sensor specs
- Choose altitude
  - Higher flight altitude means a shorter flight and less pictures, but worse resolution

Altitude (ft)	# of Images @ 70% Overlap	Resolution (in per Pixel)	Flight Time (min)
50	3060	0.32	153
100	693	0.64	35
150	270	0.96	14
200	140	1.28	7
250	75	1.60	4
300	48	1.92	3
345	30	2.24	2
395	18	2.56	1

Tetracam Resolution, # of images, and flight times at different altitudes for CSU ARDEC Field 300A

Image Resolution vs. Altitude



50ft

65ft

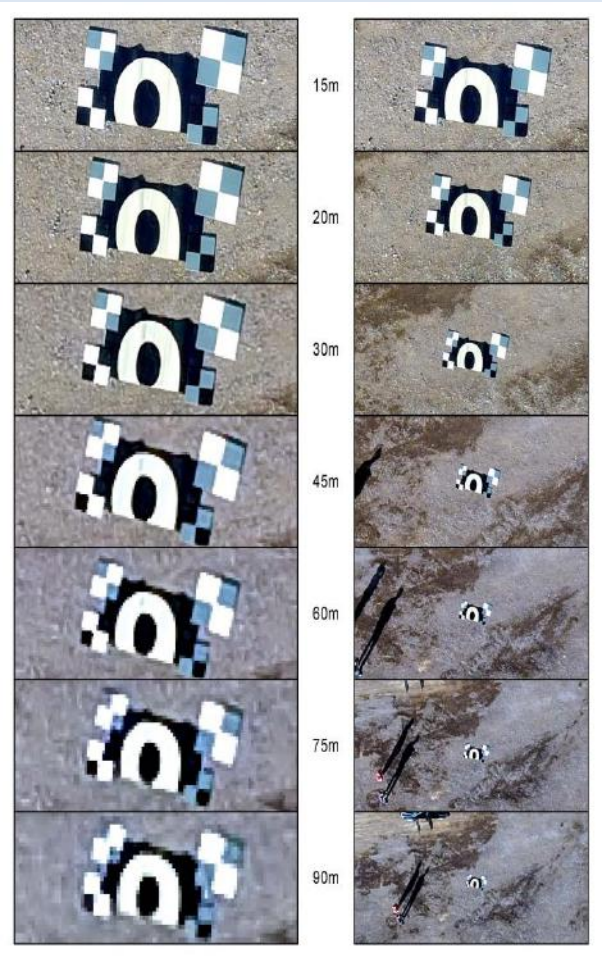
100ft

150ft

200ft

250ft

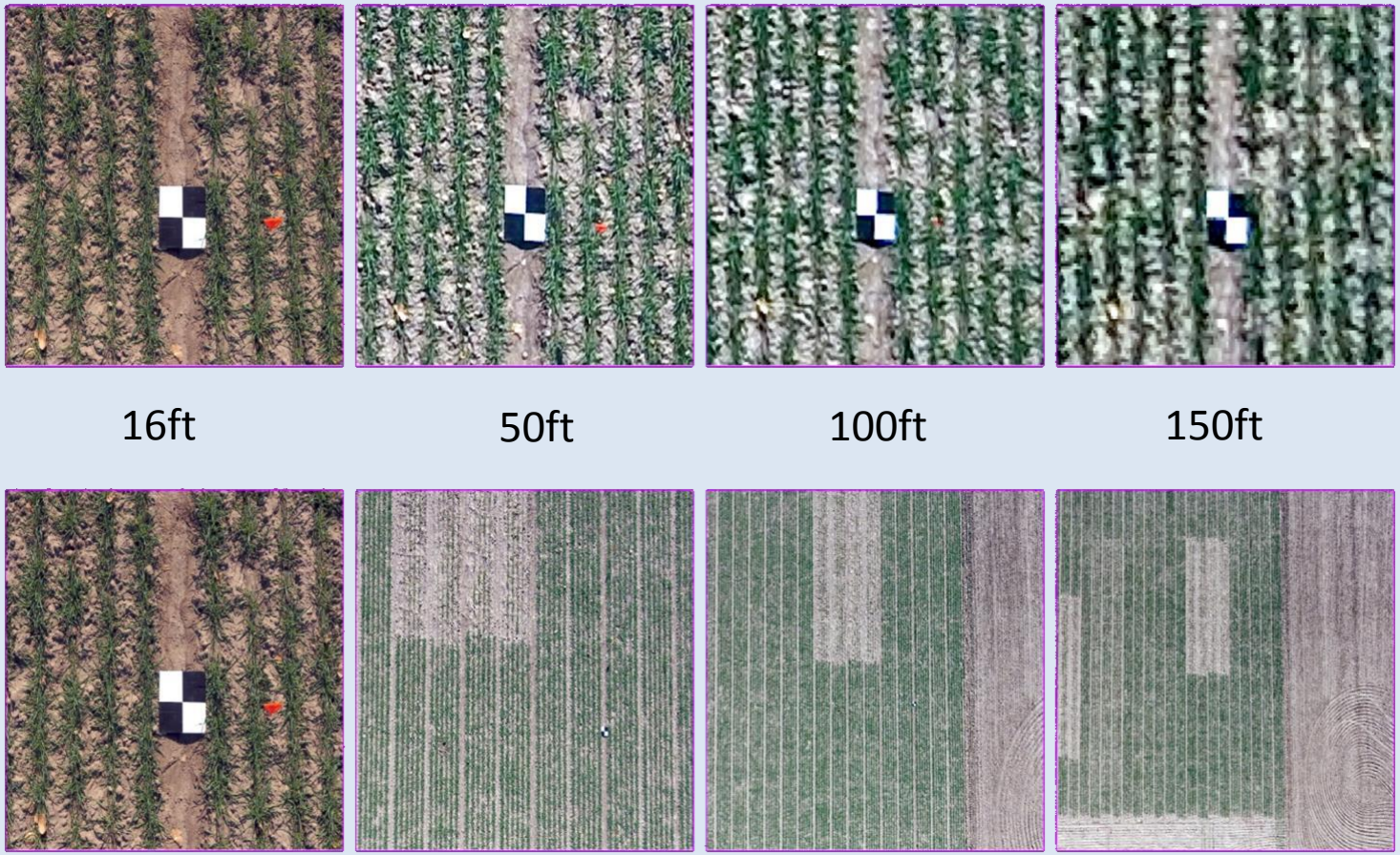
295ft



FLIR Tau 2 640 LWIR w/ 35mm Lens

DJI Phantom 4 4K RBG Camera

Image Resolution vs. Altitude (cont.)

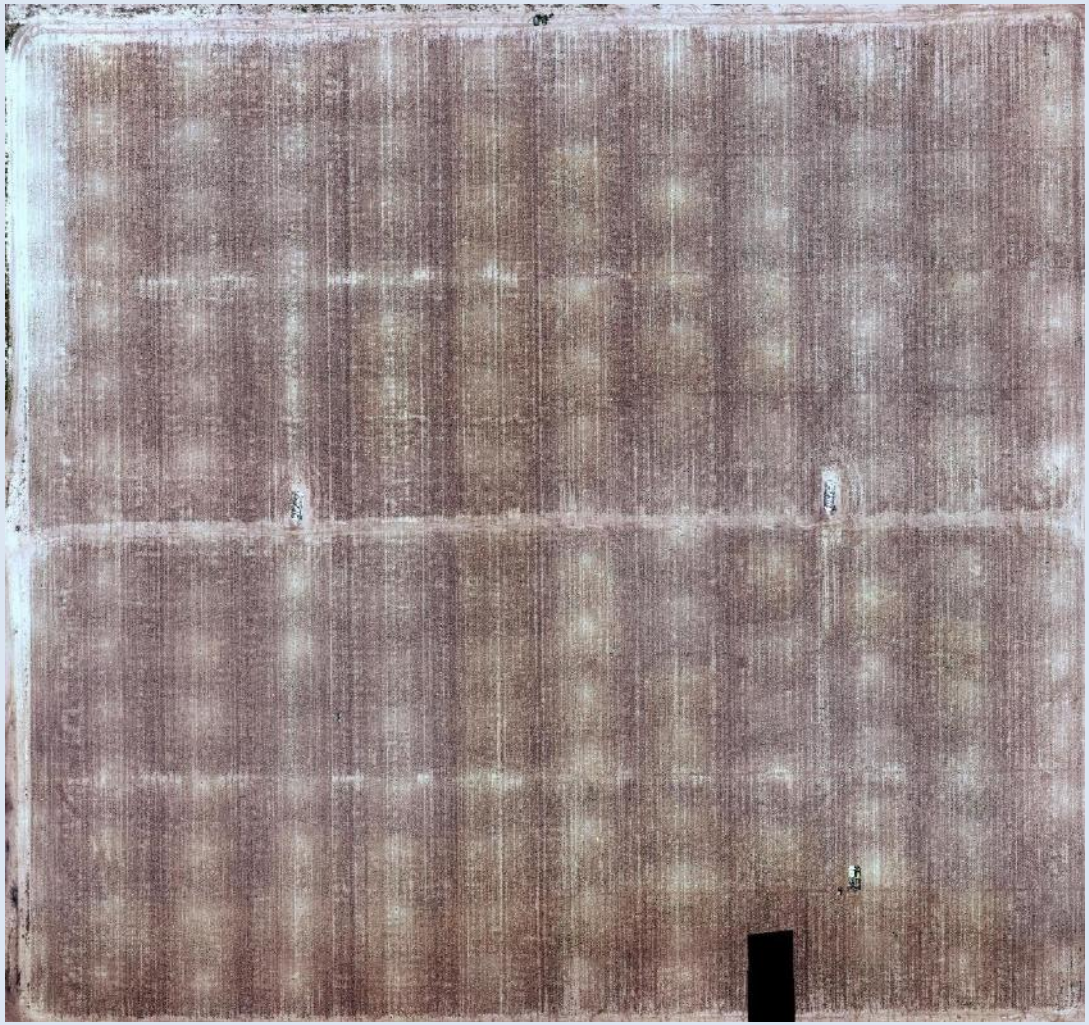


DJI Phantom 4 RGB images of wheat field taken at different altitudes. The ground control point for size reference is 12”x12” black duct tape on white tile.

Phantom 4 RGB images

- CSU ARDEC Field 300A
- The RGB image can be used to show problem spots in the field. From the RGB image of field 300A we can see spots in the field that have weeds

Phantom 4 RGB images



- LIRF Field Blocks ABCD
- Sorghum/Corn
- Field Dimensions 285 x 195 yds
- Flight plan
  - Altitude 75ft
  - 64% overlap, 40% sidelap
  - Automated flight (DJI Ground Station Pro)
  - 197 images
  - Image resolution 0.39in per pixel
- Flight Time ~20mins
- Battery Usage ~150%
- Post Processing Time (OneButton Pro) ~ 45 mins