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AERIAL SURVEYS

Five Sensors, One Day: Unmanned vs. Manned Logistics and Accuracy

ASPRS UAS Mapping Technical Symposium

Sept 13th, 2016

Presenter: David Day, CP, GISP

Keystone Aerial Surveys, Inc.

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Summary of activities

1. Set out to test as many sensors over the same location as possible during the same day
2. Location as close as possible to Northeast Philadelphia Headquarters for reduction of costs

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Manned Sensors Planned for Use

High resolution, multispectral digital image sensor

- Vexcel Ultracam Falcon Prime
  - Focal Length: 100.500 mm
  - Pixel Size: 6 µm
  - Image format: 17310 x 11310 pixels

Ultracam Falcon Prime

- Teledyne Optech Galaxy
  - Dynamic Field of View (0-60 degrees)
  - Multiple pulse capabilities
  - Record 8 range and intensity measurements per pulse
  - Unique Swath Tracking mode maintains constant-width flight lines for consistent data density in variable terrain.

Galaxy

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Manned Aircraft Planned for Use

Cessna 210 single engine aircraft for Ultracam Falcon

- Operating Ceiling of 26,000’
- Cruise speed of 190 kts
- Single camera port

Cessna 310 twin engine aircraft for Galaxy

- Operating Ceiling of 30,000’
- Cruise speed of 205 kts
- Single camera port

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UAS Planned for Use

Altavian Nova F6500 (fixed wing)

- Hand-launched
- Endurance: 90 min
- Cruise Speed: 35mph
- Altitude: 200ft AGL/10, 000ft MSL
- Wing Span: 108"
- Weight: 15lbs Maximum Take Off

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UAS Planned for Use

DJI Inspire 1 Pro (Rotorcraft)

- 4 Propellers
- Dimensions: 438mm x 451mm x 301mm
- Max Weight with payload: 3.5 kg
- Max Altitude: 4500m
- Estimated Endurance: 15 min

SteadiDrone Mavrik X8 (Rotorcraft)

- 8 Propellers
- Dimensions: 960mm x 970mm x 495mm
- Max Weight with payload: 18 kg
- Max Altitude: 4000m
- Estimated Endurance: 10 min

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Sensors Planned for Use

Altavian Canon MP22 for RGB and CIR

- Effective Pixels: 22MP
- Image Max Size: 5184x3456
- Focal Length: 20mm (effective 35mm)

Sony A7r on Mavrik

- Effective Pixels: 36.4MP
- Image Max Size: 7360x4912
- Sony/Zeiss FE 35mm f/2.8

DJI X5 RGB

- Effective Pixels: 16M
- Image Max Size: 4608x3456
- Focal Length: 12mm

DJI X3 modified for CIR (NDVI)

- Effective Pixels: 12.4M
- Image Max Size: 4000x3000
- Focal Length: 9mm

Applanix APX-15 IMU\GNSS for Sony A7r

- Post processed GPS positional accuracy up to 0.02 meter
- Roll & Pitch up to 0.025 degrees
- 60 grams weight without customized housing

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Planned Location and Flights

- AGA Farms in Perkasie, PA
- 10 acres AOI on 100 acre farm
- Fully compatible with 333 rules working under at the time

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Planned Location and Flights

- Falcon Prime: 2cm and 4cm
- Galaxy @ 18 ppm2
- Altavian RGB: 400ft & 200 ft
- Altavian CIR: 400ft & 200 ft
- Mavrik RGB: 200ft & 400 ft (with and without IMU)
- DJI Inspire RGB: 200ft & 400 ft
- DJI Inspire CIR: 200ft & 400 ft

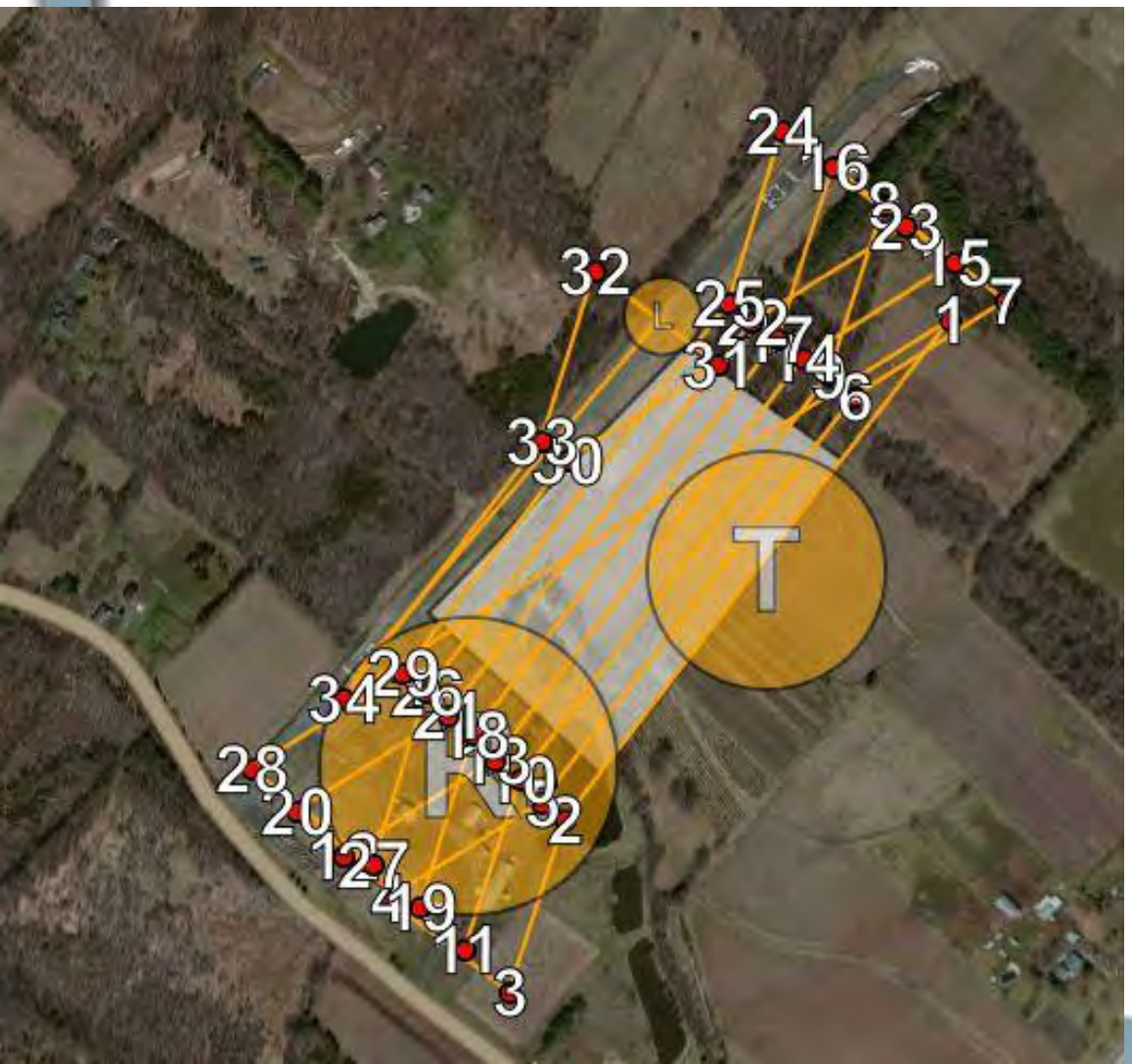
Planned Location and Flights

UltraCam Falcon 2cm GSD

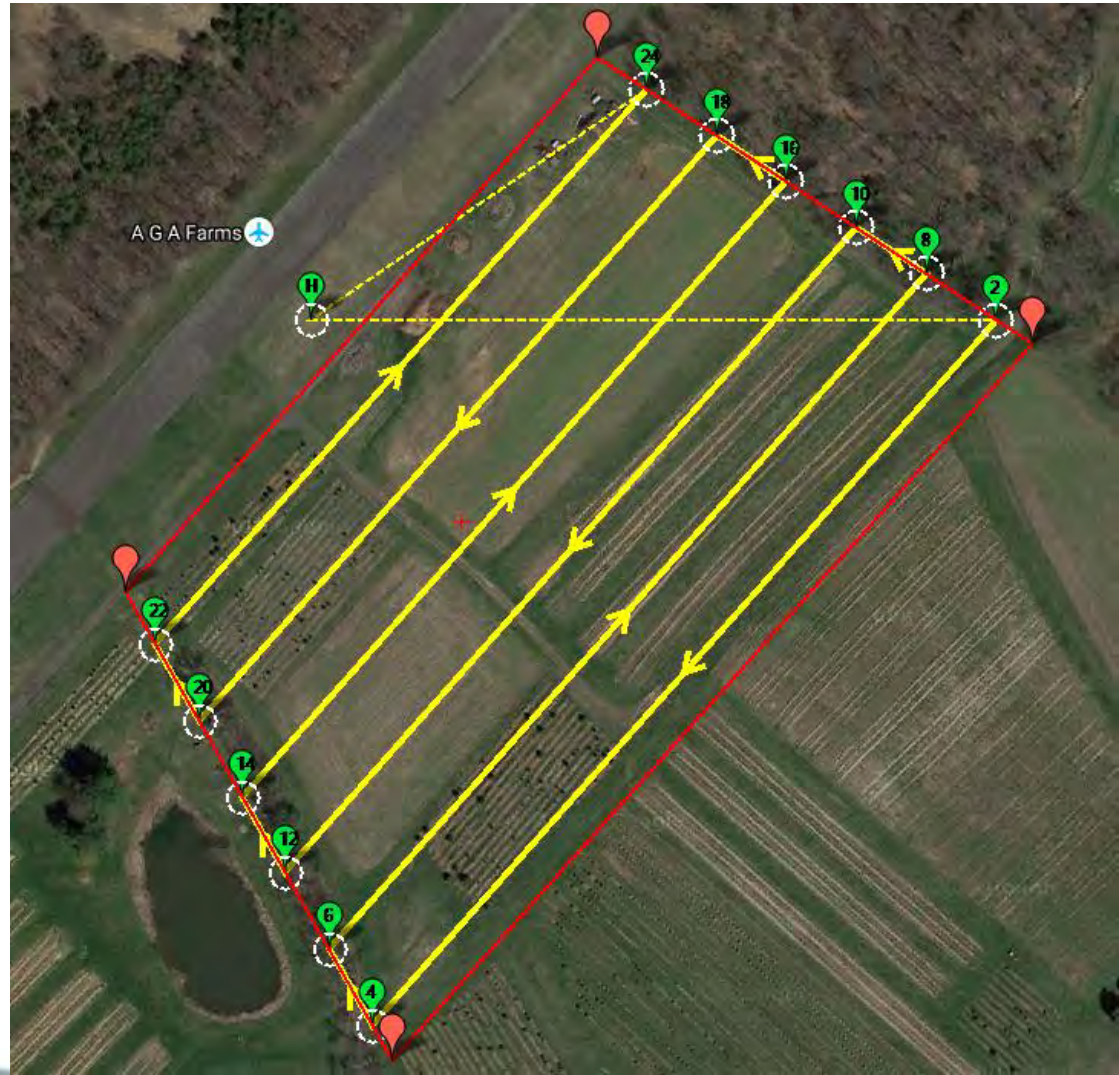
Galaxy Flight Plan

Planned Location and Flights

Altavian MP22 400ft Plan



Sony A7r 200ft Plan



Purpose: Education

- Enable Keystone to fully understand what data can be produced and with what confidence
- Develop methods for acquisition and post production
- Highlight proper coordination and communication between manned aircraft pilots and unmanned pilots/observers
- Share with the industry

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Purpose

- Many applications available today with a drone purchase or as a service
  - Drone Deploy claim that over 6 Million acres have been mapped by their users
- With new rules, there will be a flood of new suppliers (estimates as high as 600,000) competing with the traditional mapping, survey, engineering and other fields due to the software advances

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So if . . .

“Anyone Can Cook!”

Ratatouille – 2007 Pixar animated movie

Can Anyone Map?

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Timeline

- Ground Control Placed: June 28th
- Galaxy flown: June 29th 7:44 am local time
- Altavian: 10:00 – 10:10 am
- UltraCam Falcon: 10:33 – 10:39 am
- Mavrik: 10:42 – 10:52 am
- UltraCam Falcon: 10:46- 10:52am
- Altavian: 11:06 – 11:20 am
- Mavrik: 11:45 – 11:54 am
- Altavian: 12:14 – 12:36 pm

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Crew and communication logistics

- Best to have a second crew member for fixed wing operations
- Best to have a second crew member for congested airspace
- Multiple pilots allowed for easy transition between UAS types
- Generator a MUST for powering ground stations and recharging batteries
- Internet connection extremely important for re-planning flights on the fly – what can be done when there is no cell phone coverage? Or it is too slow to tether from a device?

- Confirm all firmware on aircraft, sensors, batteries match before leaving Office

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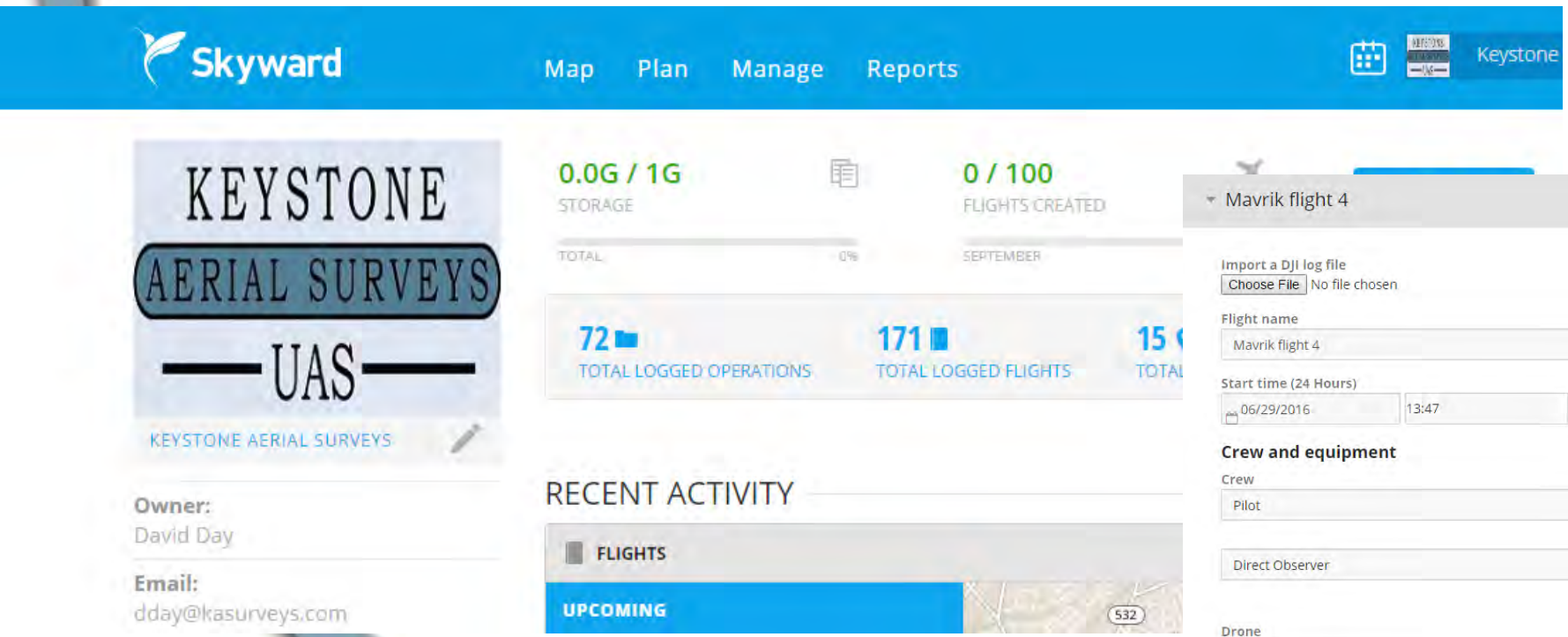
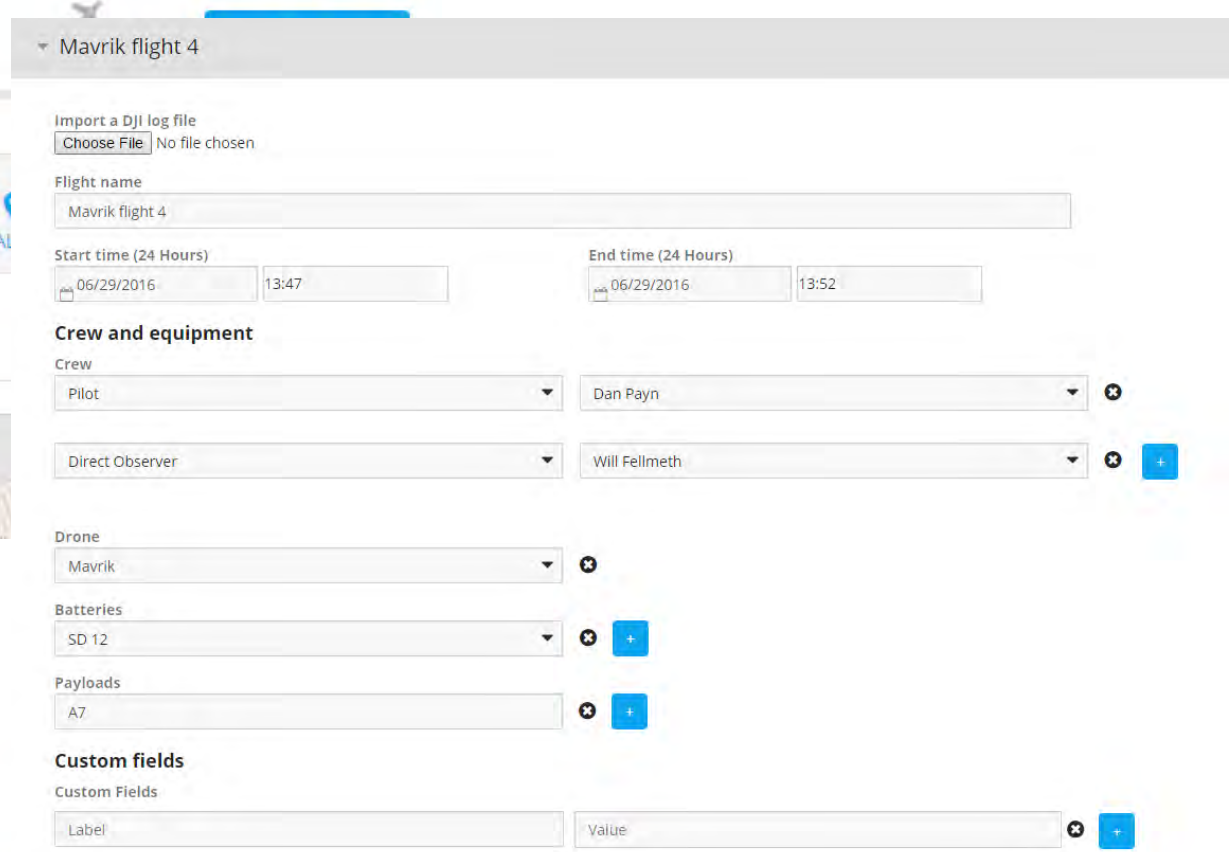
Crew and communication logistics

Crew and communication logistics

- Flight Logging





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Planned vs. Actual

- IMU not ready in time – had to return several weeks later with working prototype
- DJI x5 camera would not properly communicate – total failure of camera that required a return to manufacturer
- DJI x3 camera was not properly configured in software for unique lens so imagery captured could not be used

Capture Statistics

Platform	Sensor	Bands	GSD	Altitude	Lines	Images	Time
Cessna 210	UC FalconP	RGBI	4cm	2575 ft	2	20	4 min
Cessna 210	UC FalconP	RGBI	2cm	1375 ft	3	48	6 min
F6500	Cannon	RGB	2.76cm	400 ft	7	192	6 min
F6500	Cannon	RGB	1.38cm	200 ft	9	231	11 min
F6500	Cannon	CIR	2.76cm	400 ft	7	192	6 min
F6500	Cannon	CIR	1.38cm	200 ft	9	231	11 min
Mavrik	Sony	RGB	1.47cm	400 ft	4	72	5 min
Mavrik	Sony	RGB	0.72cm	200 ft	7	285	13 min

The Galaxy captured the area in 5 strips in 9 minutes of production flight time. The point density averaged 17.8 points per square meter using a PRF of 300 kHz and a scan frequency of 92 Hz at an altitude of 3000 feet AGL.

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Results of AT – RMSE on Check Points

	DX in cm			DY in cm			DZ in cm		
Flight	**2GCP**	**3GCP**	**5GCP**	**2GCP**	**3GCP**	**5GCP**	**2GCP**	**3GCP**	**5GCP**
Sony 200ft	5.141	2.722	2.695	3.199	2.031	2.302	37.619	20.686	3.939
Sony 400ft	2.555	1.866	1.398	2.848	1.449	1.532	19.233	21.539	6.116
Cannon 200ft	4.875	3.211	2.739	4.726	4.456	2.916	21.369	20.770	6.995
Cannon 400ft	3.021	1.825	1.283	1.323	0.857	1.351	10.011	12.296	5.314
UCFp 1387ft	1.900	1.668	1.000	1.700	1.400	0.700	4.100	2.700	2.900
UCFp 2560ft	2.200	1.200	1.200	2.000	2.100	1.300	3.800	3.700	3.500

2 GCPs used resulted in 13 Check Points
3 GCPS resulted in 12 Check Points
5 GCPs resulted in 10 Check Points

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Results of AT

As an alternative to Pix4D, Keystone tried Correlator 3D from Simactive on the Sony imagery at 200ft with 3 GCPs and with 5 GCPs

RMSE CM 3GCP	X	Y	Z
Correlator3D	2.09	2.76	4.64
Pix4D	2.72	2.03	20.69

RMSE CM 5GCP	X	Y	Z
Correlator3D	2.23	2.29	4.49
Pix4D	2.70	2.30	3.94

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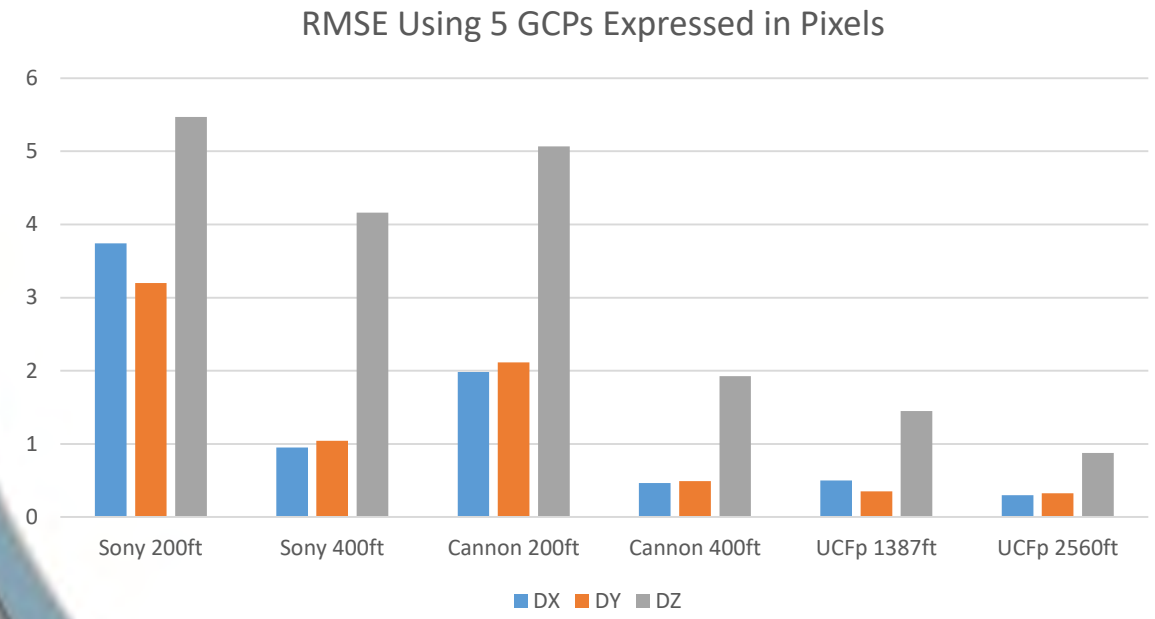
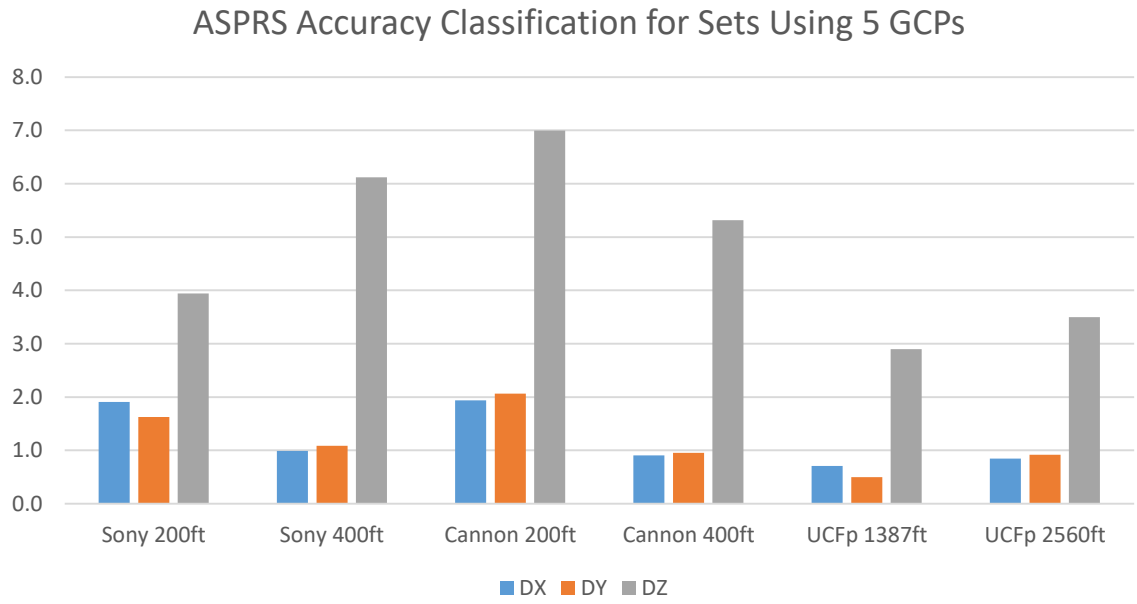
Results of AT





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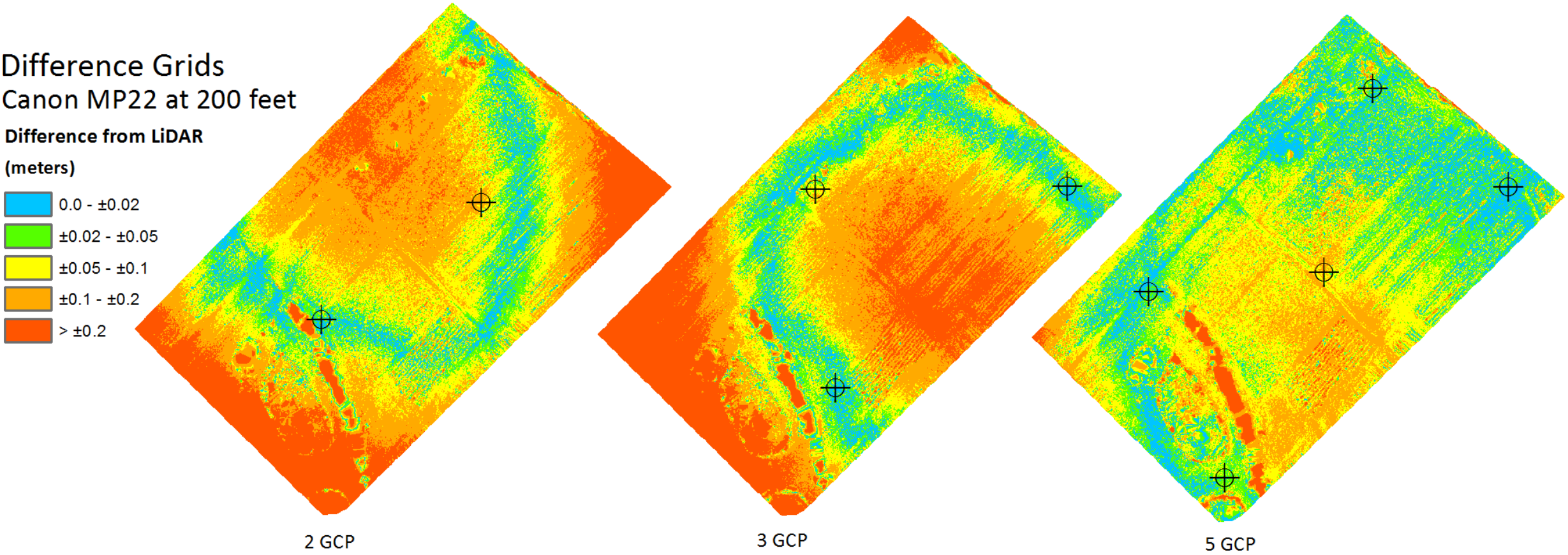
Results of Height Comparisons



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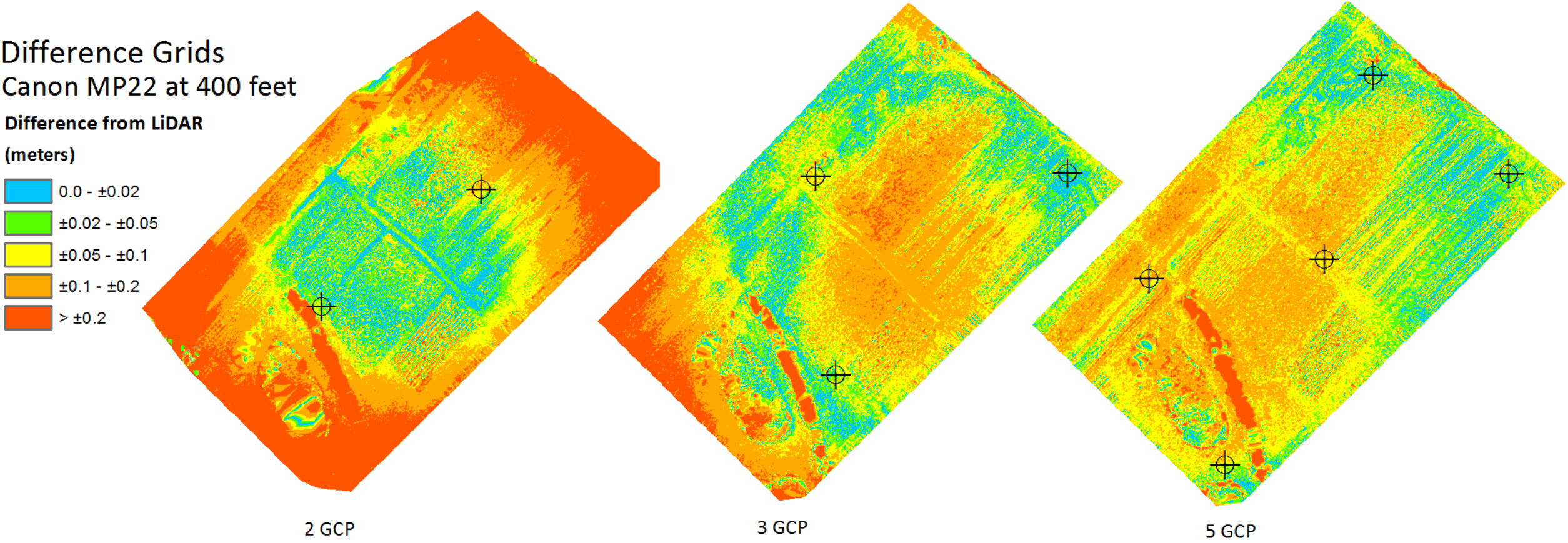
A custom Python script using ArcGIS 10.4's ArcPy library was written to procedurally subtract each photogrammetric DEM from the LiDAR DEM. The resulting difference grid shows the deviation between the model and the LiDAR model.

Results of Height Comparisons



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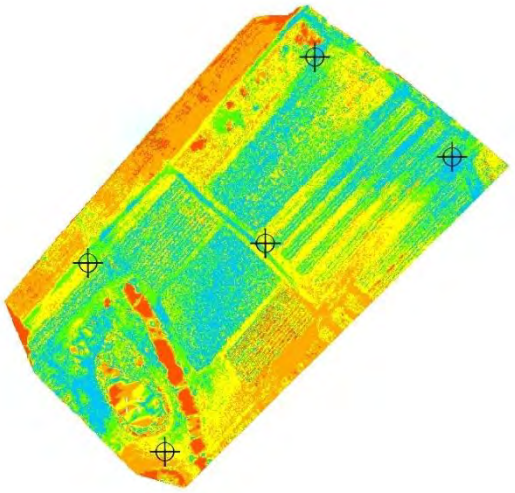
Results of Height Comparisons

Difference Grid
Sony a7R at 200 feet

Difference from LiDAR
(meters)

- 0.0 - ±0.02
- ±0.02 - ±0.05
- ±0.05 - ±0.1
- ±0.1 - ±0.2
- > ±0.2

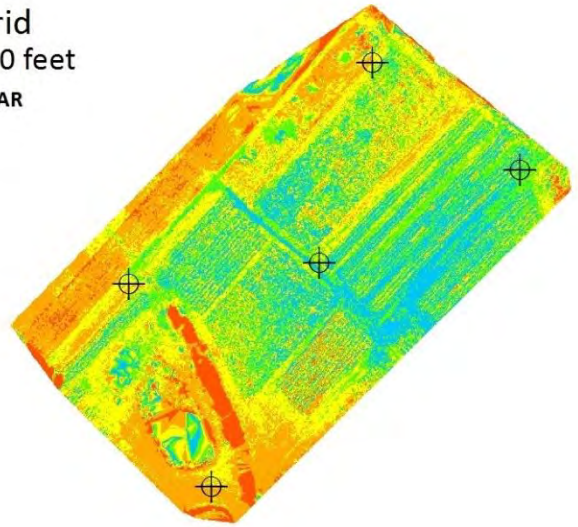


5 GCP

Difference Grid
Sony a7R at 400 feet

Difference from LiDAR
(meters)

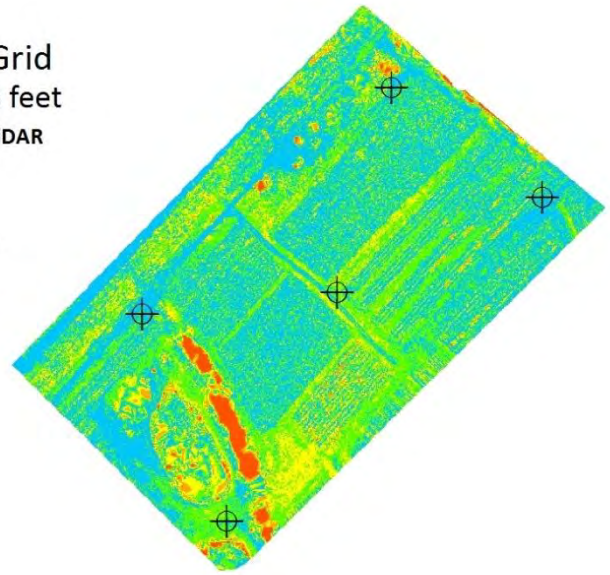
- 0.0 - ±0.02
- ±0.02 - ±0.05
- ±0.05 - ±0.1
- ±0.1 - ±0.2
- > ±0.2



Difference Grid
UCFp at 1375 feet

Difference from LiDAR
(meters)

- 0.0 - ±0.02
- ±0.02 - ±0.05
- ±0.05 - ±0.1
- ±0.1 - ±0.2
- > ±0.2

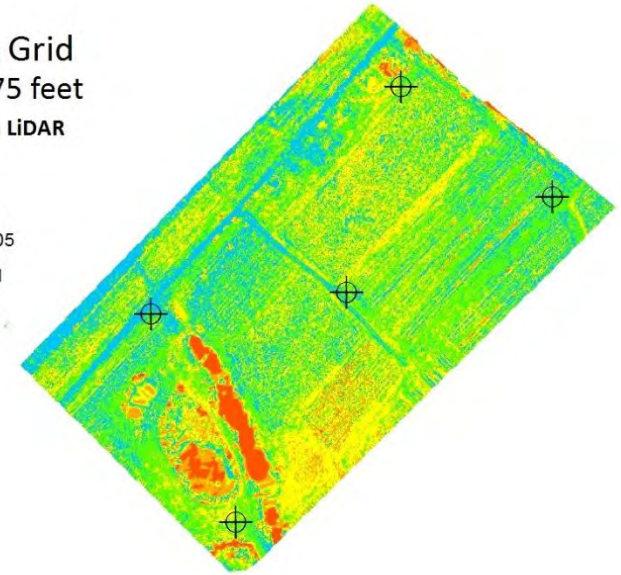


5 GCP

Difference Grid
UCFp at 2575 feet

Difference from LiDAR
(meters)

- 0.0 - ±0.02
- ±0.02 - ±0.05
- ±0.05 - ±0.1
- ±0.1 - ±0.2
- > ±0.2



5 GCP

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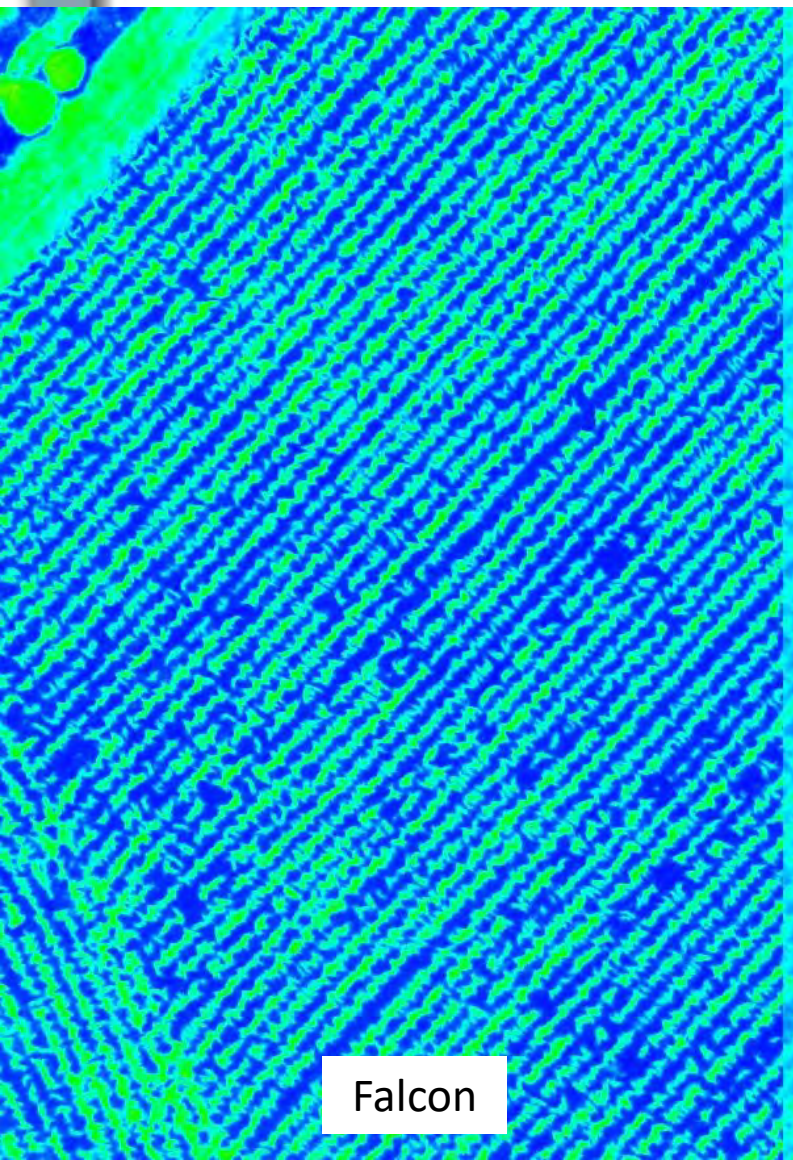
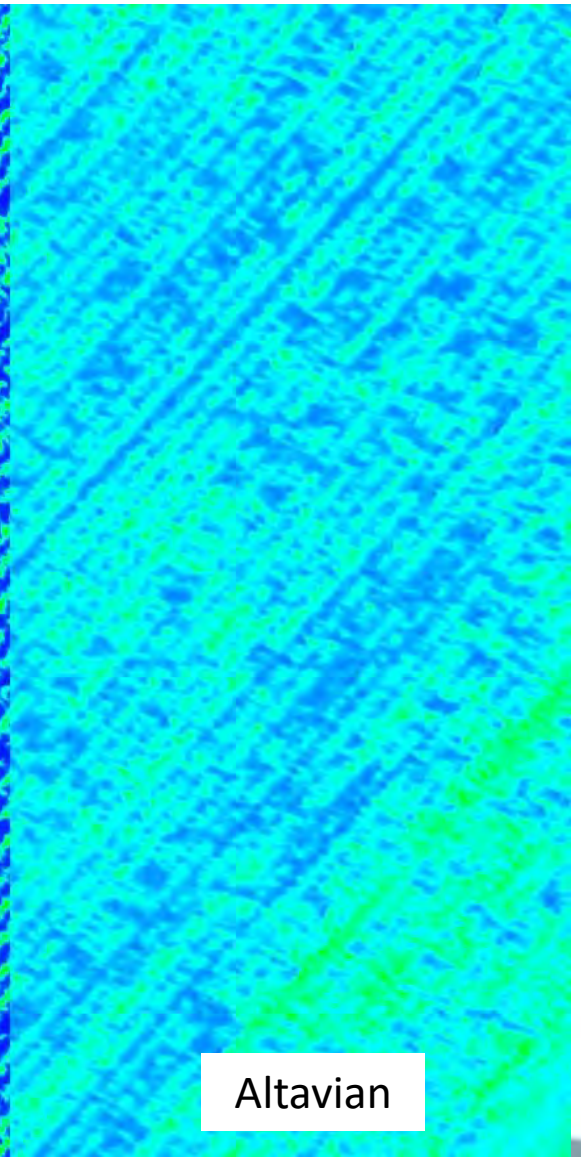
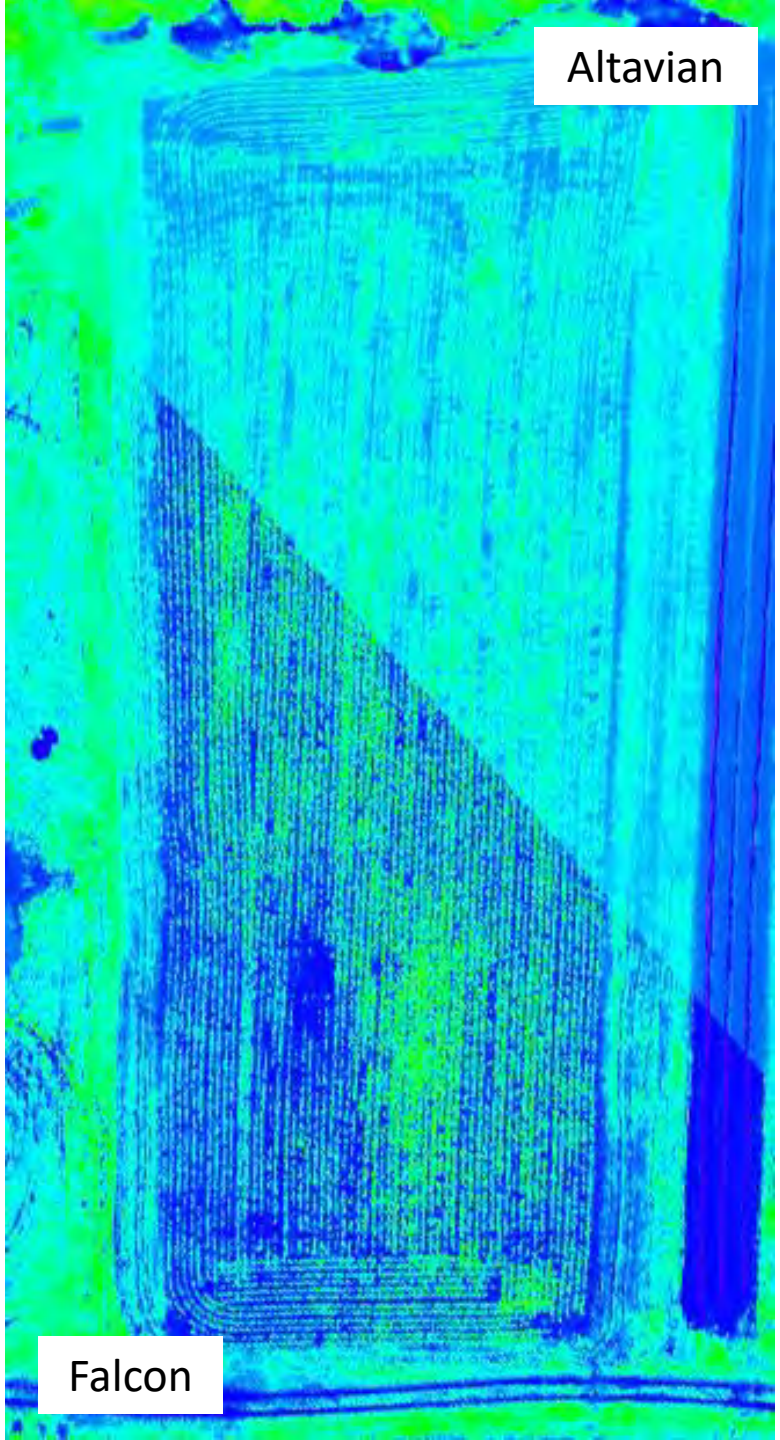
NDVI Comparison







Video

https://youtu.be/RPZjrwfJHnE

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Takeaways

Lens Stability and Understanding of Software is Key

- The Canon 22MP camera mounted on the fixed wing aircraft performed better than the Sony A7R 36MP camera on the rotorcraft in lower control situations. However, with more control, the Sony sensor produced accuracies comparable to the UCFp.
- Despite the high quality Zeiss 35mm lens on the Sony A7R, the adjustments performed by the software would suggest an instability in the lens. In the case of the Zeiss lens, the situation of less control caused the errors to manifest without the ability to be systematically corrected.

Takeaways

Altitude Should Be Chosen By Product

- Each camera performed better with less control at the larger pixel sizes suggesting that the increased image amount affected the overall quality.
- The very high resolution images resulted in fewer obvious ground features and more image uniformity, resulting in more false-positive tie points. While this was the case in triangulation, the higher resolution imagery resulted in better residuals in Z when comparing the check points to both bare earth and surface model products. This suggests a trade-off must be considered before a survey is conducted.

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Thank You!

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