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.
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
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

- 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.
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
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
**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
Sensors Planned for Use

Altavion 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
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
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
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
So if . . .

“Anyone Can Cook!”

*Ratatouille* – 2007 Pixar animated movie

Can Anyone Map?
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
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
Crew and communication logistics
Crew and communication logistics

- Flight Logging
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

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

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.
## Results of AT – RMSE on Check Points

<table>
<thead>
<tr>
<th>Flight</th>
<th>DX in cm</th>
<th>DY in cm</th>
<th>DZ in cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2GCP</td>
<td>3GCP</td>
<td>5GCP</td>
</tr>
<tr>
<td>Cannon 400ft</td>
<td>3.021</td>
<td>1.825</td>
<td>1.283</td>
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<tr>
<td>UCFp 1387ft</td>
<td>1.900</td>
<td>1.668</td>
<td>1.000</td>
</tr>
<tr>
<td>UCFp 2560ft</td>
<td>2.200</td>
<td>1.200</td>
<td>1.200</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Correlator3D</strong></td>
<td>2.09</td>
<td>2.76</td>
<td>4.64</td>
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<tr>
<td><strong>Pix4D</strong></td>
<td>2.72</td>
<td>2.03</td>
<td>20.69</td>
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<td>2.29</td>
<td>4.49</td>
</tr>
<tr>
<td><strong>Pix4D</strong></td>
<td>2.70</td>
<td>2.30</td>
<td>3.94</td>
</tr>
</tbody>
</table>
Results of AT

RMSE Using 5 GCPs Expressed in Pixels

ASPRS Accuracy Classification for Sets Using 5 GCPs
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

Difference Grids
Canon MP22 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

2 GCP
3 GCP
5 GCP
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

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

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
NDVI Comparison
Video

https://youtu.be/RPZjrwfJHnE
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.
Thank You!

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