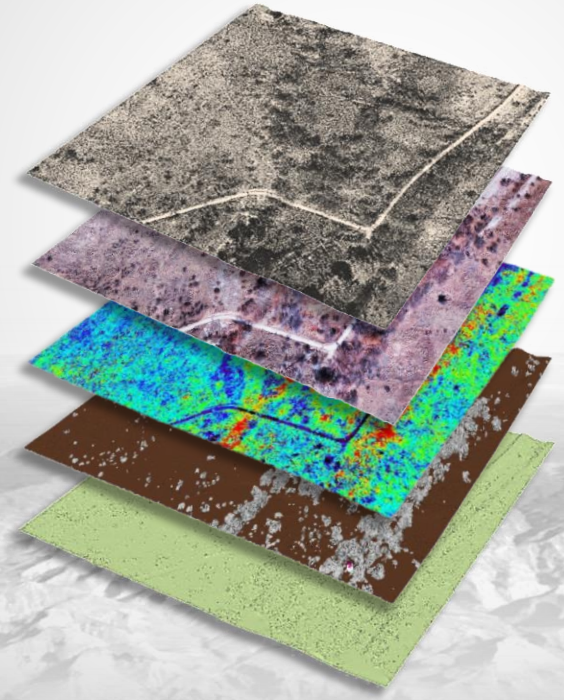
# National Unmanned Aircraft Systems (UAS) Project Office

USGS
science for a changing world



3-D POINT CLOUD DATA

DIGITAL SURFACE MODELS

DIGITAL TERRAIN MODELS

ORTHOIMAGERY

SEGMENTATION AND CLASSIFICATION

U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

USGS
science for a changing world

# Modeling Devils Tower, WY using UAS

## Highlighting UAS data acquisition methods for baseline comparisons.

This proof of concept project attempts to address questions regarding conditions of **rock quality**, **potential rock fall locations**, **vegetative health**, and **peregrine falcon nesting** locations, and understanding the **habitat** of various **bat species** at Devils Tower. The data also provides the National Park Service an accurate model for recreational **climbing routes**, and planning **rescue operations** for public safety.

*Devils Tower Point Cloud and Textured Model*

**Primary Goal:** **To model a 3D surface, capturing the color reflectance accurately, and minimizing sources of error.**

Devils Tower National Monument located in northeastern Wyoming is a prominent monolith of igneous rock rising 867 feet above the surrounding landscape.

U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

USGS science for a changing world

# Modeling Devils Tower, WY using UAS

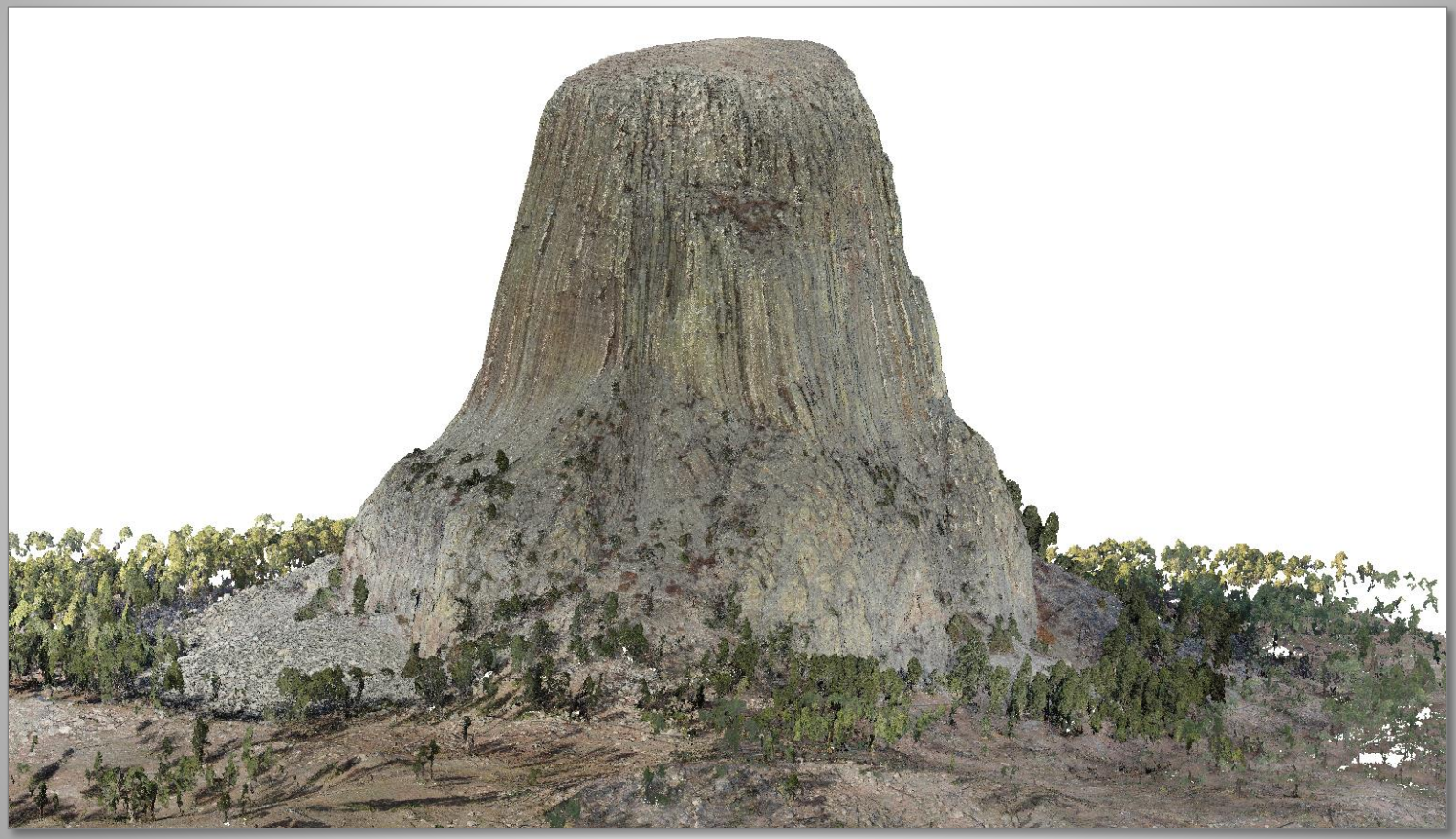
Highlighting UAS data acquisition methods for baseline comparisons.

*Devils Tower Textured Model*

U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

# Modeling Devils Tower, WY using UAS

## Highlighting UAS data acquisition methods for baseline comparisons.



*Devils Tower Dense Point Cloud*

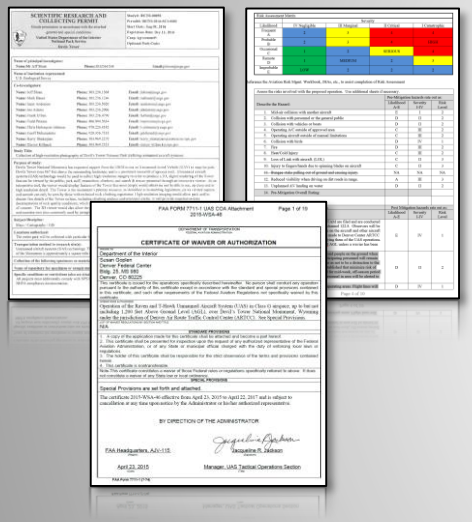
U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

USGS
science for a changing world

# Modeling Devils Tower, WY using UAS

Highlighting UAS data acquisition methods for baseline comparisons.

## Planning and Approval



- Class G MOA with FAA
- Blanket COA
- **COA Wavier**
- Part 107 rules

## UAS System


- 3DR Solo with Ricoh GR
- Surveyed Ground Control

## Flight Testing, Acquisition, Processing & Products

- Point Cloud, DSM, DEM, Orthoimage
- Agisoft Photoscan

U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

USGS science for a changing world

# Modeling Devils Tower, WY using UAS

## Highlighting UAS data acquisition methods for baseline comparisons.


**3DR Solo Quadcopter UAS**

- Pixhawk Auto Pilot
- Freq 2.4 Ghz
- Weight 3.3 lbs.
- Flight Time with Payload:  10 minutes
- Range: 0.5 miles
- Max speed  25 m/s
- Collection Speed: 10 m/s
- Compatible with Mission Planner and Tower Applications

**Pentax Ricoh GR I & II Camera (APS-C Sensor)**

- Fixed lens  18 mm focal length
- Sensor size  23.70 mm x 15.70 mm
- Focus lock to infinity.  (Contrast based system)
- Captures both RAW (DNG) and JPG files
- Bit Depth of RAW 12 bits, 8 Bit for JPGs

U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

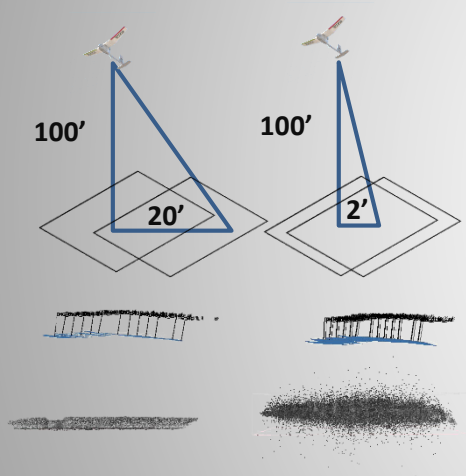
USGS
science for a changing world

# Modeling Devils Tower, WY using UAS

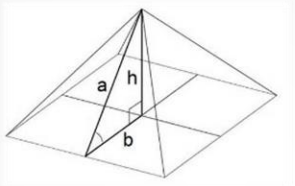
Highlighting UAS data acquisition methods for baseline comparisons.

## The importance of having good geometry in your image acquisition.

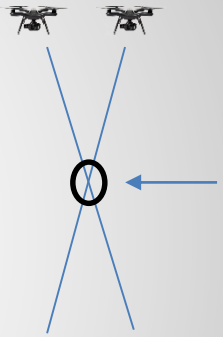
### Base to Height Ratio



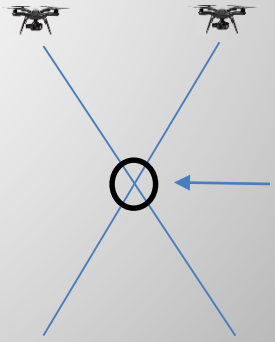

- 1:1 ratio equals about 20% overlap
- 1:2.3 ratio equals about 66% overlap
- 1:5.2 ratio equals about 85% overlap
- 1:7.2 ratio equals about 90% overlap




- Your ability to measure depth (z) goes down when your base to height ratio goes up. This is a direct relationship of photo geometry.
- Base to Height Ratio between 1:2.3 and 1:5.2 is ideal.
- Geometry with Base to Height Ratio of 1:5 has 5 times more potential for error in Z than 1:1



More uncertainty in your height measurement.



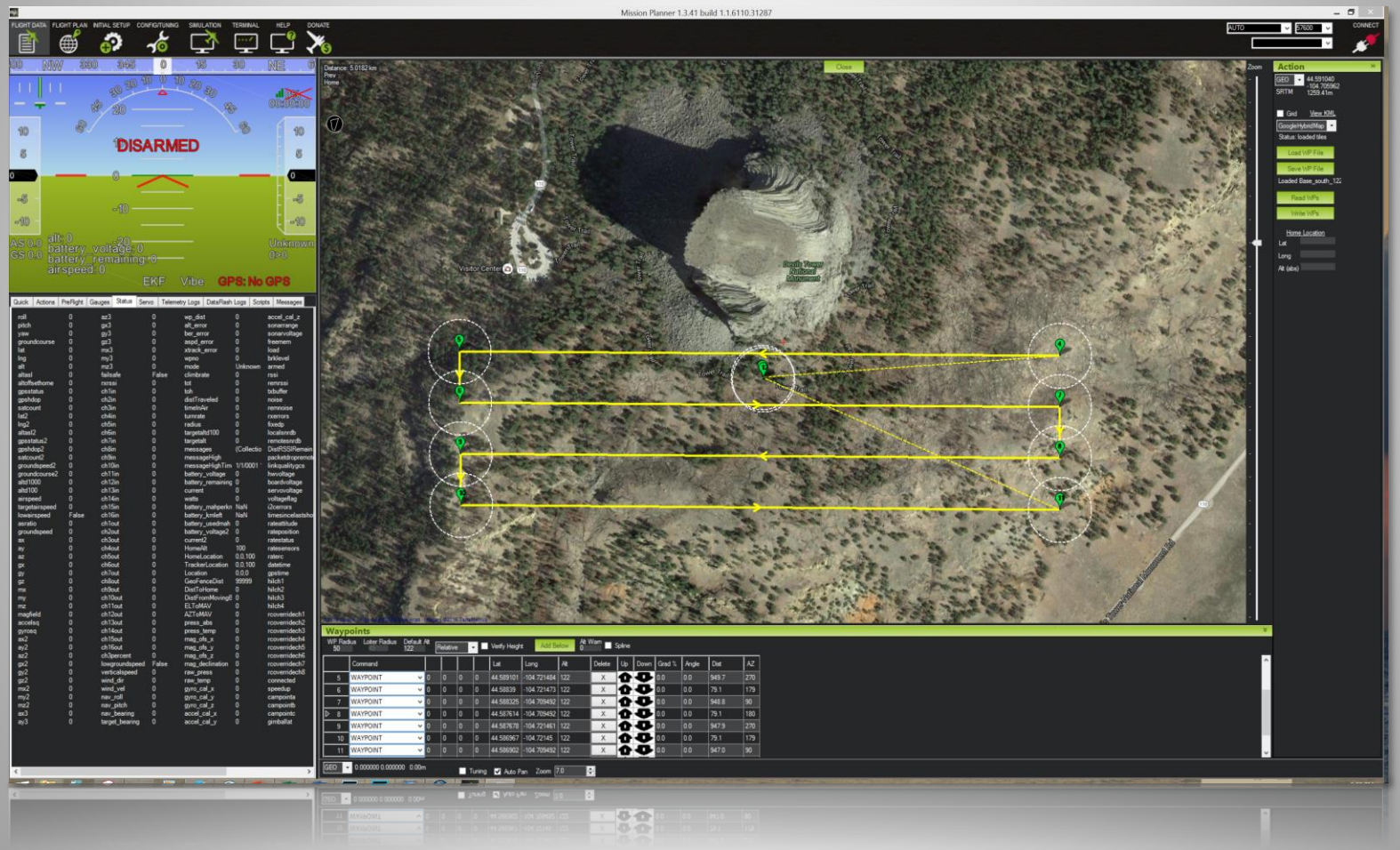
Less uncertainty in your height measurement.

U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

USGS science for a changing world

# Modeling Devils Tower, WY using UAS

## Highlighting UAS data acquisition methods for baseline comparisons.

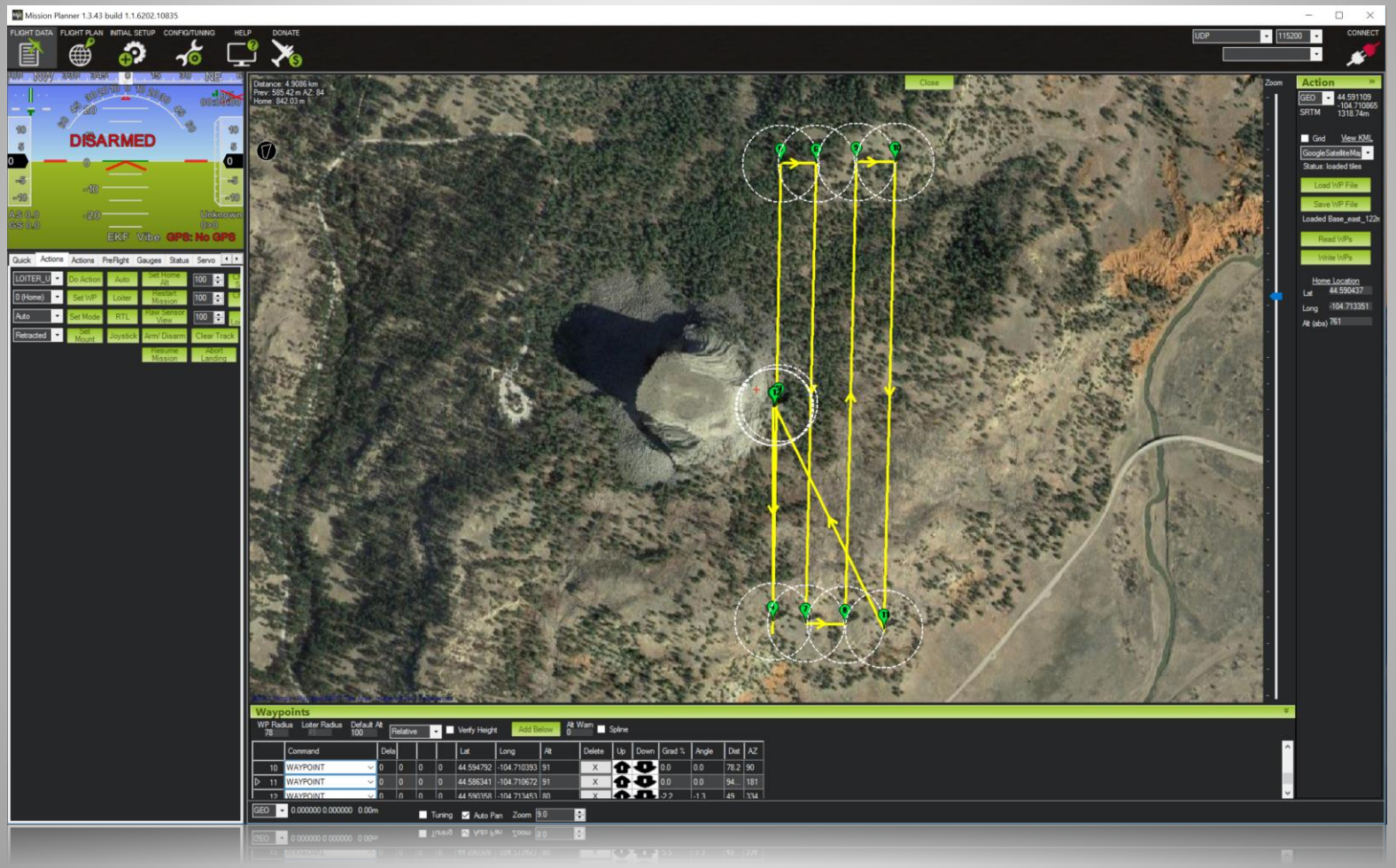



U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

USGS
science for a changing world

# Modeling Devils Tower, WY using UAS

## Highlighting UAS data acquisition methods for baseline comparisons.




U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

USGS science for a changing world

# Modeling Devils Tower, WY using UAS

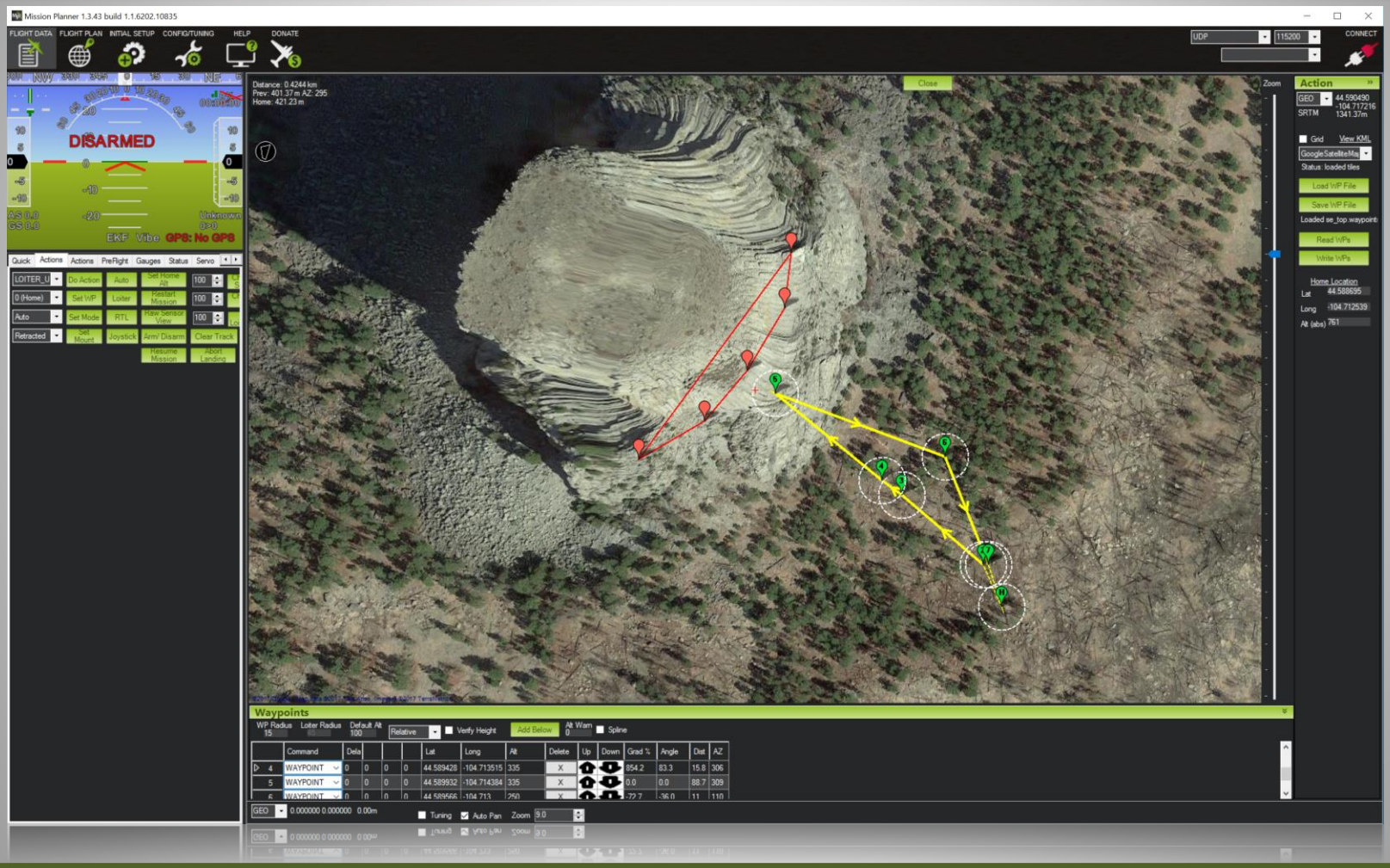
## Highlighting UAS data acquisition methods for baseline comparisons.


U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

USGS science for a changing world

# Modeling Devils Tower, WY using UAS

## Highlighting UAS data acquisition methods for baseline comparisons.



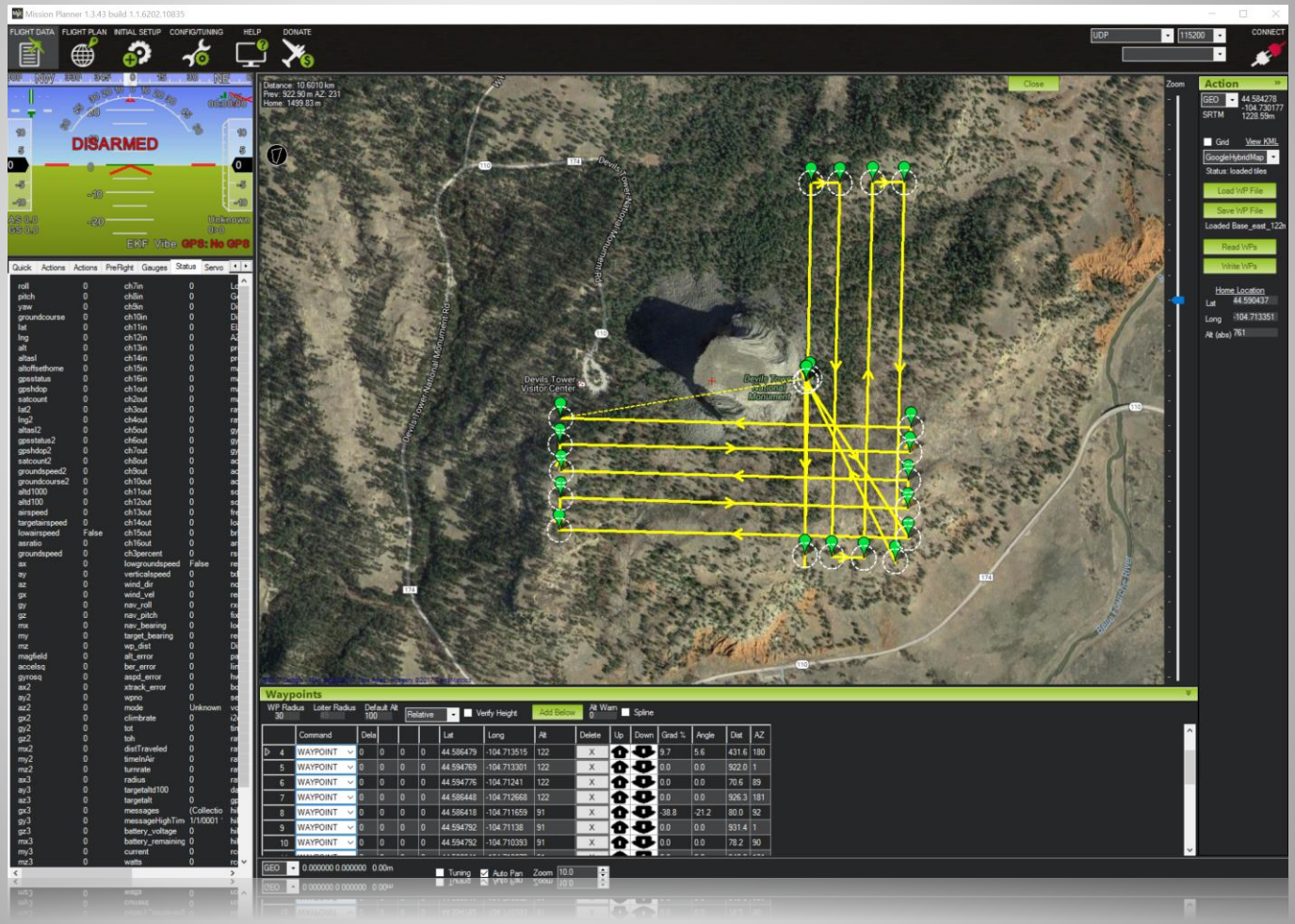

U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

USGS science for a changing world

# Modeling Devils Tower, WY using UAS

## Highlighting UAS data acquisition methods for baseline comparisons.

- **Multiple Camera orientations will help map the camera calibration by locating the center position (principle point) of your image. Rotating your camera at 0°, 90°, 270° is ideal.**

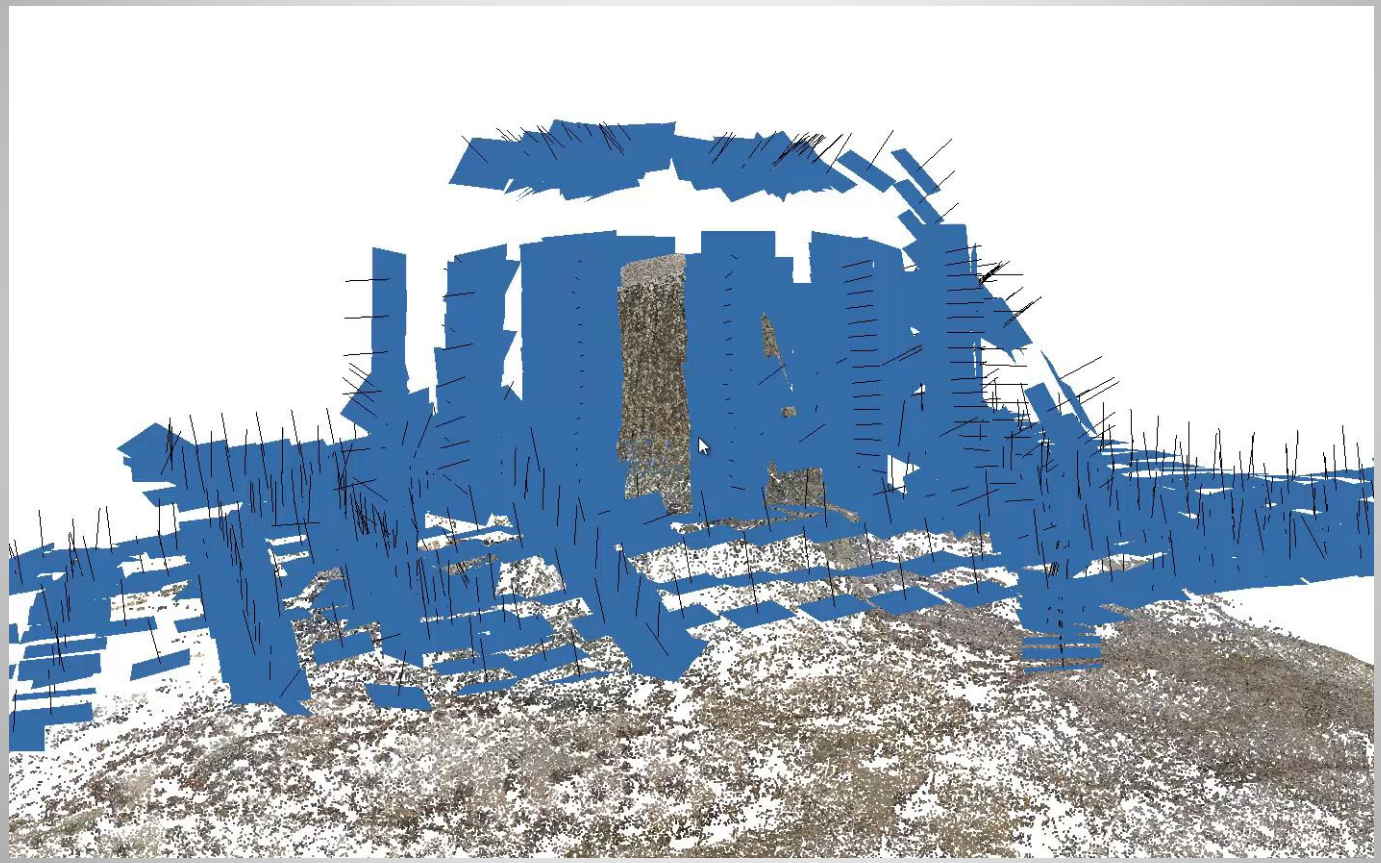



U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

USGS science for a changing world

# Modeling Devils Tower, WY using UAS

## Highlighting UAS data acquisition methods for baseline comparisons.



Camera Orientations

U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

USGS
science for a changing world

# Modeling Devils Tower, WY using UAS

Highlighting UAS data acquisition methods for baseline comparisons.

U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

USGS
science for a changing world

# Modeling Devils Tower, WY using UAS

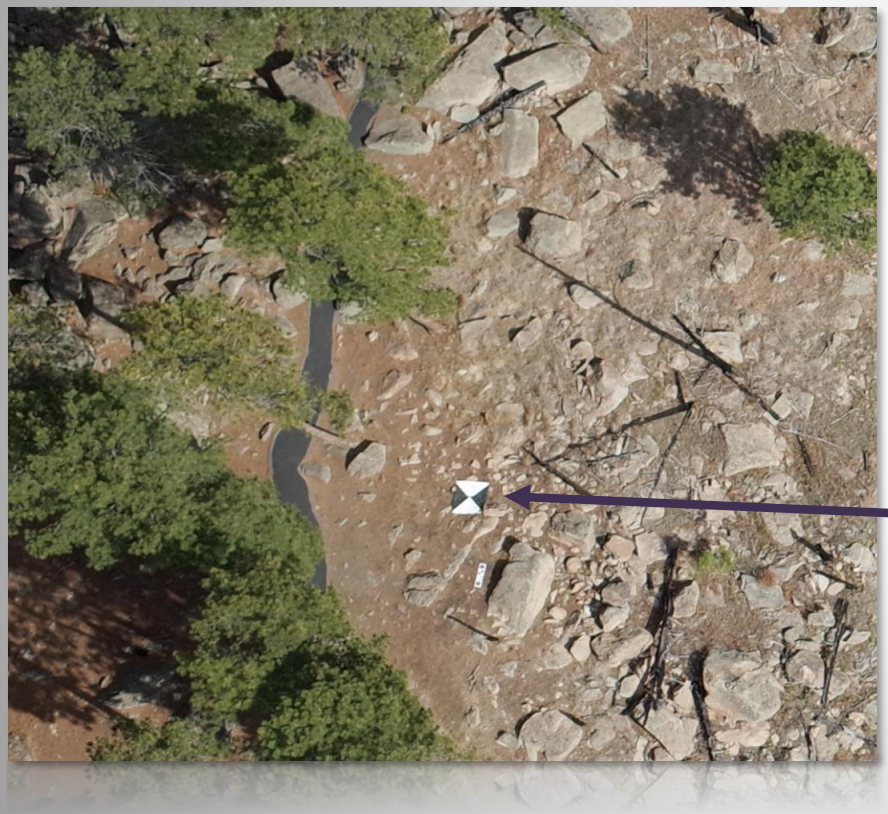
## Highlighting UAS data acquisition methods for baseline comparisons.

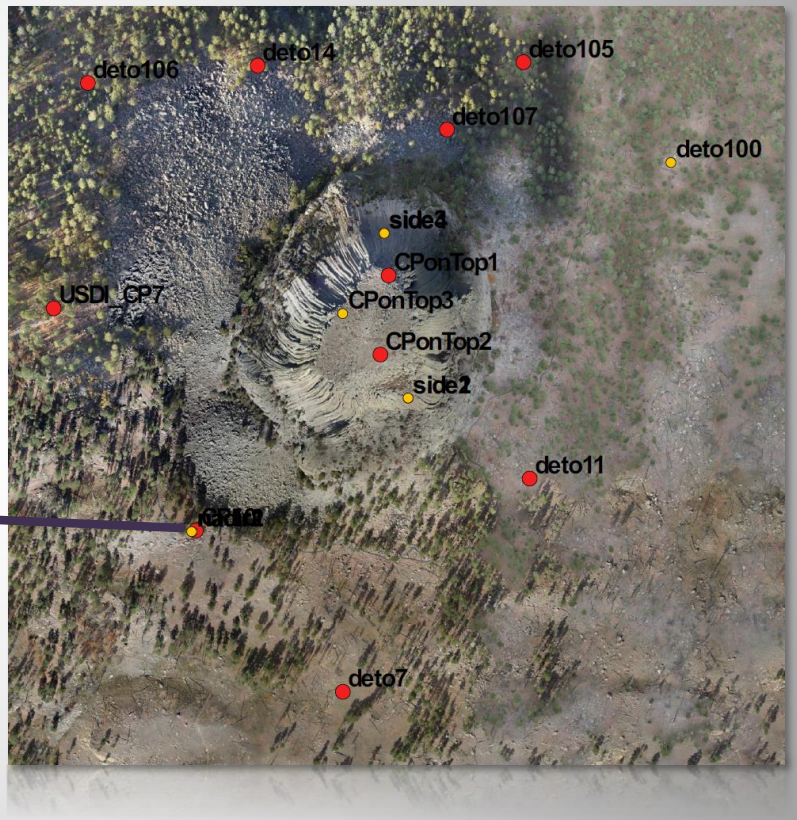

U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

USGS
science for a changing world

# Modeling Devils Tower, WY using UAS

Highlighting UAS data acquisition methods for baseline comparisons.






U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

USGS
science for a changing world

# Modeling Devils Tower, WY using UAS

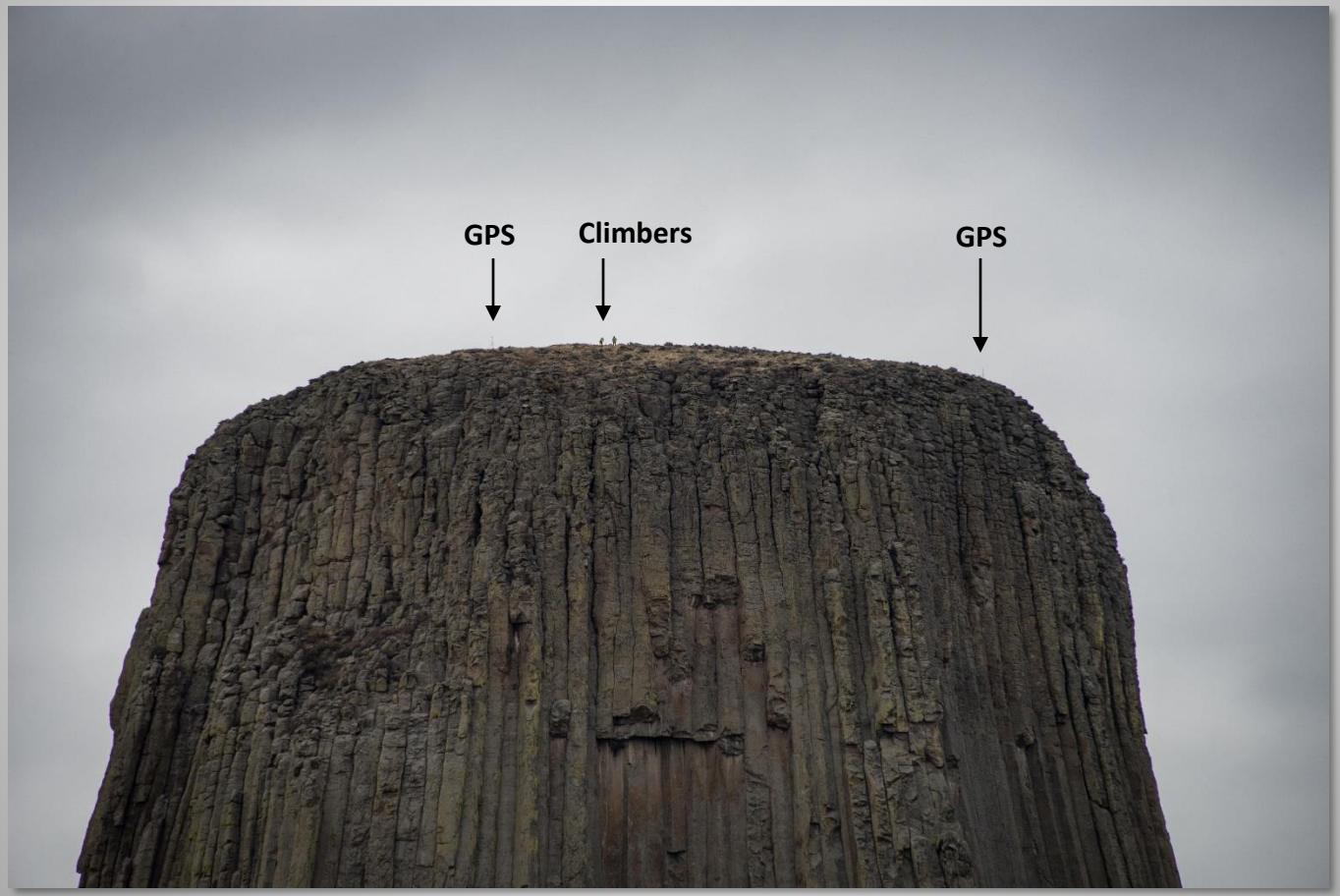
Highlighting UAS data acquisition methods for baseline comparisons.

U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

USGS
science for a changing world

# Modeling Devils Tower, WY using UAS

Highlighting UAS data acquisition methods for baseline comparisons.

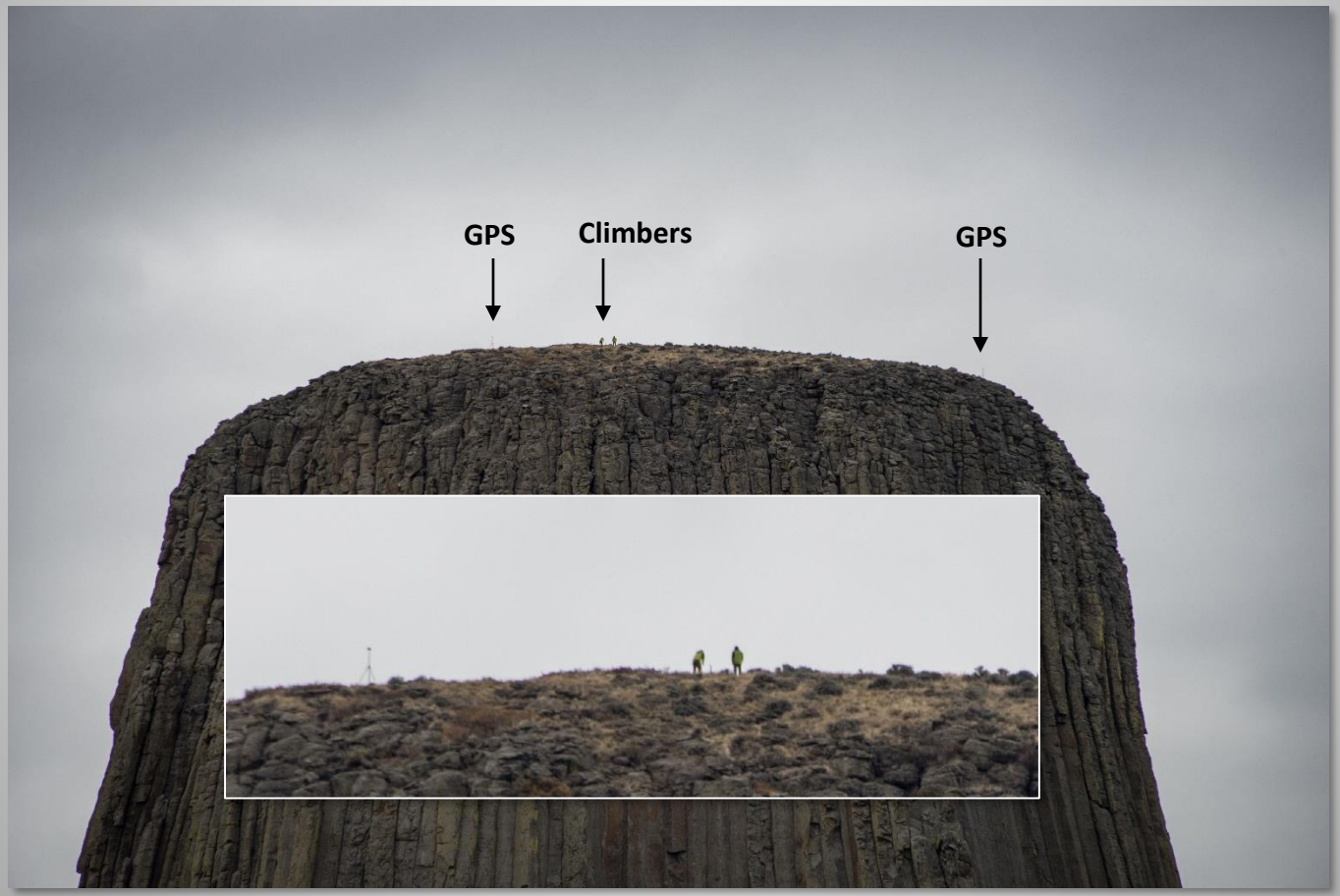



U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

USGS
science for a changing world

# Modeling Devils Tower, WY using UAS

Highlighting UAS data acquisition methods for baseline comparisons.

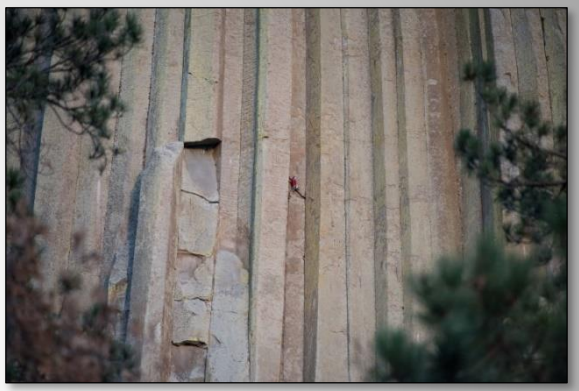



U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

USGS
science for a changing world

# Modeling Devils Tower, WY using UAS

Highlighting UAS data acquisition methods for baseline comparisons.



U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

USGS
science for a changing world

# Modeling Devils Tower, WY using UAS

Highlighting UAS data acquisition methods for baseline comparisons.

U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

USGS
science for a changing world

# Modeling Devils Tower, WY using UAS

## Highlighting UAS data acquisition methods for baseline comparisons.

## Photogrammetric Report

### Ortho Image Summary

| | | | |
|---|---|---|---|
| Number of images: | 809 | Camera stations: | 809 |
| Flying altitude: | 147 m | Tie points: | 618,041 |
| Ground resolution: | 3.53 cm/pix | Projections: | 2,241,084 |
| Coverage area: | 0.558 km² | Reprojection error: | 0.263 pix |

### Ground Control Points RMSE

| Label | X error (cm) | Y error (cm) | Z error (cm) | Total (cm) | Image (pix) |
|---|---|---|---|---|---|
| deto11 | 2.5041 | 2.16326 | 10.7171 | 11.2163 | 0.215 (10) |
| deto7 | -1.49484 | -0.47488 | 1.20406 | 1.97733 | 0.105 (5) |
| deto14 | -0.156844 | -2.34243 | -0.0677996 | 2.34866 | 0.275 (8) |
| deto107 | 2.18357 | -5.49961 | 7.35378 | 9.43884 | 0.160 (9) |
| deto105 | 2.7803 | 6.89048 | -18.6033 | 20.0323 | 0.187 (4) |
| CP10 | -1.46693 | 0.807657 | -6.94755 | 7.14651 | 0.241 (11) |
| deto106 | -3.77399 | -0.150071 | 4.33852 | 5.75224 | 0.392 (4) |
| CPonTop2 | -0.19539 | -1.19665 | -0.944201 | 1.53677 | 0.149 (13) |
| CPonTop1 | -0.0796314 | -3.71326 | -6.10402 | 7.14519 | 0.189 (9) |
| USDI_CP7 | 1.6186 | 2.28796 | 3.00323 | 4.1078 | 0.247 (4) |
| **Total** | **2.00217** | **3.30525** | **7.94188** | **8.83214** | **0.216** |

### Scale Bars RMSE

| Label | Distance (m) | Error (m) |
|---|---|---|
| side1_side2 | 0.768245 | 0.00941963 |
| side3_side4 | 0.770459 | 0.011634 |
| nadir1_nadir2 | 0.770847 | 0.012022 |
| **Total** | | **0.0110846** |

### Camera Calibration Report

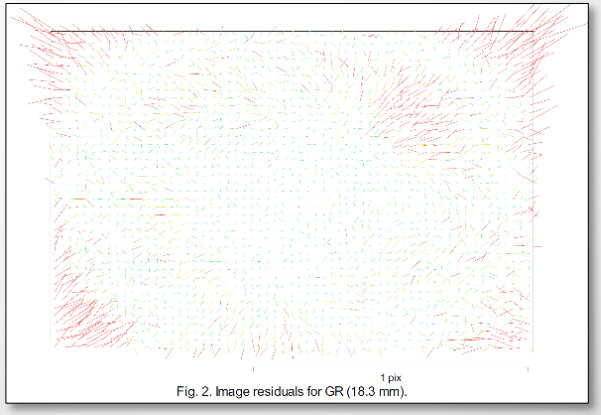
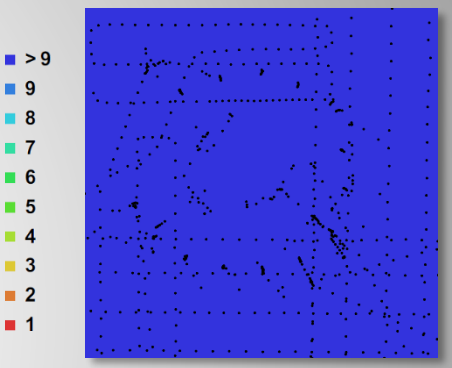


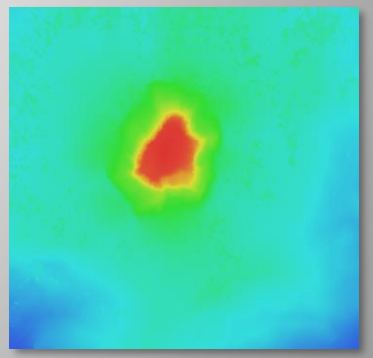
Fig. 2. Image residuals for GR (18.3 mm).

### Image Overlap




### Elevation

| | |
|---|---|
| Resolution: | 14.1 cm/pix |
| Point density: | 50.2 points/m² |



U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

USGS science for a changing world

# Modeling Devils Tower, WY using UAS

## Highlighting UAS data acquisition methods for baseline comparisons.

## Photogrammetric Report

### Ortho Image Summary

| | | | |
|---|---|---|---|
| Number of images: | 809 | Camera stations: | 809 |
| Flying altitude: | 147 m | Tie points: | 618,041 |
| Ground resolution: | 3.53 cm/pix | Projections: | 2,241,084 |
| Coverage area: | 0.558 km² | Reprojection error: | 0.263 pix |

### Ground Control Points RMSE

| Label | X error (cm) | Y error (cm) | Z error (cm) | Total (cm) | Image (pix) |
|---|---|---|---|---|---|
| deto11 | 2.5041 | 2.16326 | 10.7171 | 11.2163 | 0.215 (10) |
| deto7 | -1.49484 | -0.47488 | 1.20406 | 1.97733 | 0.105 (5) |
| deto14 | -0.156844 | -2.34243 | -0.0677996 | 2.34866 | 0.275 (8) |
| deto107 | 2.18357 | -5.49961 | 7.35378 | 9.43884 | 0.160 (9) |
| deto105 | 2.7803 | 6.89048 | -18.6033 | 20.0323 | 0.187 (4) |
| CP10 | -1.46693 | 0.807657 | -6.94755 | 7.14651 | 0.241 (11) |
| deto106 | -3.77399 | -0.150071 | 4.33852 | 5.75224 | 0.392 (4) |
| CPonTop2 | -0.19539 | -1.19665 | -0.944201 | 1.53677 | 0.149 (13) |
| CPonTop1 | -0.0796314 | -3.71326 | -6.10402 | 7.14519 | 0.189 (9) |
| USDI_CP7 | 1.6186 | 2.28796 | 3.00323 | 4.1078 | 0.247 (4) |
| **Total** | **2.00217** | **3.30525** | **7.94188** | **8.83214** | **0.216** |

### Scale Bars RMSE

| Label | Distance (m) | Error (m) |
|---|---|---|
| side1_side2 | 0.768245 | 0.00941963 |
| side3_side4 | 0.770459 | 0.011634 |
| nadir1_nadir2 | 0.770847 | 0.012022 |
| **Total** | | **0.0110846** |

### Camera Calibration Report

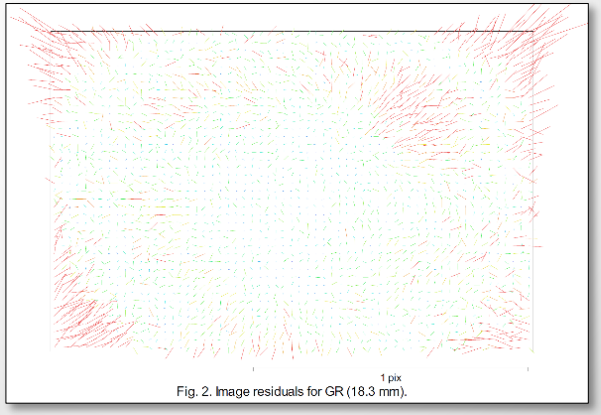
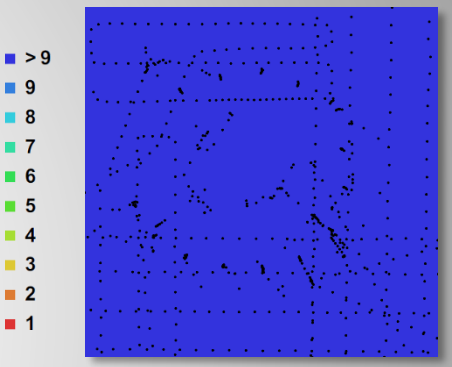


Fig. 2. Image residuals for GR (18.3 mm).

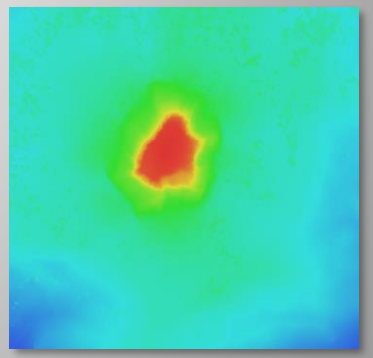
1.) Use auto detection for our markers.
2.) Camera calibrate each flight in separate sub-groups.
3.) Replace low quality photos and poor geometry images.

### Image Overlap




### Elevation

Resolution: 14.1 cm/pix
Point density: 50.2 points/m²



U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
March 2017

USGS science for a changing world

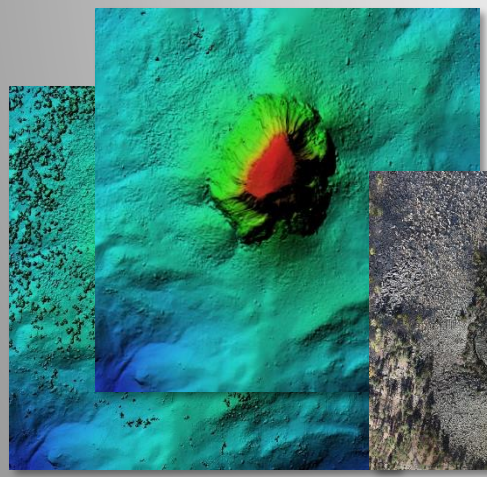
# Modeling Devils Tower, WY using UAS

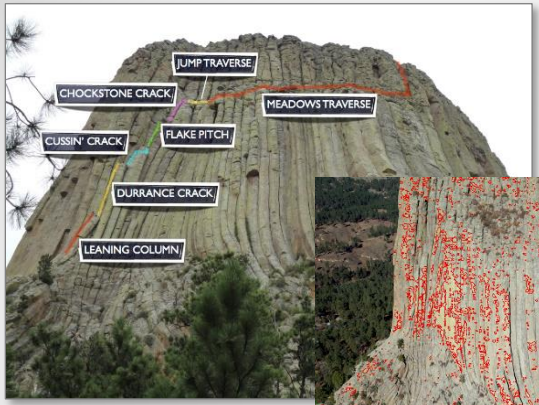
## Highlighting UAS data acquisition methods for baseline comparisons.

### Cartographic Products

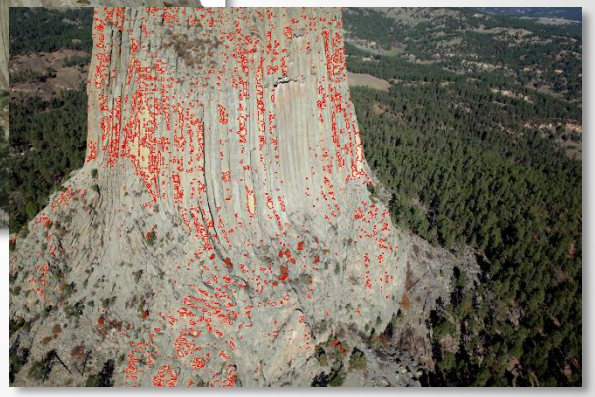
Bat Habitats

Surface Models and Bald Earth Terrain Modeling

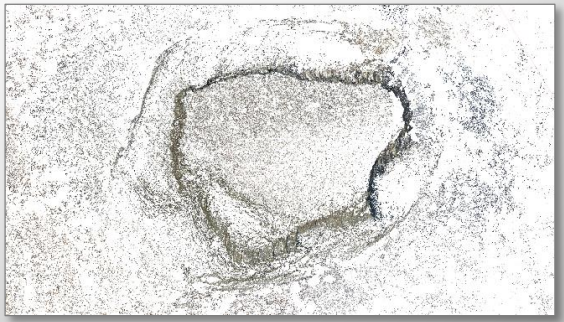




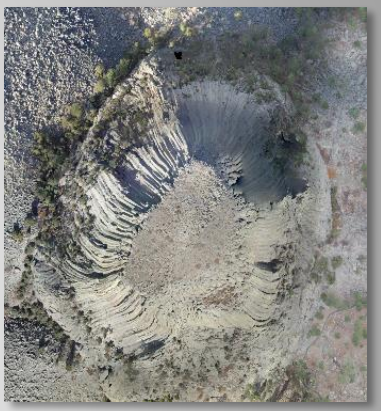

Climbing Routes & Impact Studies



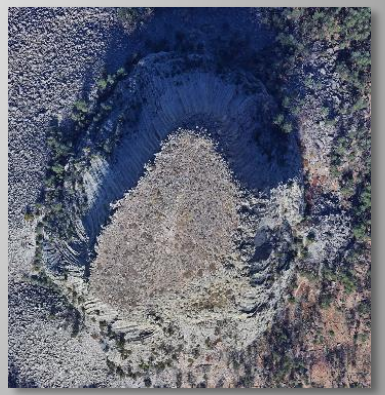
Vegetation Classification



3D Printing
(visitor center)



Acquisition Controlled to Remove Shadows



U.S. GEOLOGICAL SURVEY - NATIONAL UNMANNED AIRCRAFT SYSTEMS PROJECT OFFICE
GEOSCIENCES AND ENVIRONMENTAL CHANGE SCIENCE CENTER
DENVER, COLORADO
August 2016

USGS
science for a changing world

# National Unmanned Aircraft Systems (UAS) Project Office

## Thank You!
## Contact Our Team

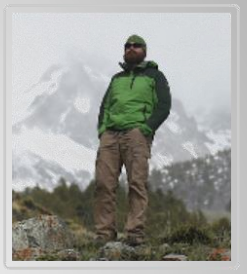

**Jeff Sloan**
Team Lead & Data Analysis
Phone: 303-236-1308
Email: jlsloan@usgs.gov



**Mark Bauer**
Mission Operator & Data Analysis
Phone: 303-236-1247
Email: mabauer@usgs.gov



**Joe Adams**
Mission Operator & Data Management
Phone: 303-236-2906
Email: jdadams@usgs.gov


**Todd Burton**
Mission Operator & Data Anaylsis
Phone: 303-236-1302
Email: tburton@usgs.gov



**Jill Cress**
Project & Web Manager
Phone: 303-236-1248
Email: jjcress@usgs.gov



**Isaac Anderson**
Mission Operator & Data Analysis
Phone: 303-236-5020
Email: ianderson@usgs.gov



**Bill Christiansen**
National Aviation Manager
USGS
Phone: 303-236-5513
Email: wdchrist@usgs.gov



**Bruce Quirk**
RPAS Liaison
Phone: 703-648-5736
Email : quirk@usgs.gov