

Applications for Unmanned Aircraft Systems (UAS) and Machine Learning to Locate and Record Archaeological Sites and Historic Trails

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Adam Calkins Background

- B.A. from Eastern Washington University in Anthropology/ Archaeology
- M.A. from University of Nevada, Reno in Anthropology/ Archaeology
- Archaeologist at The United States Forest Service
- Over six years experience in the public (government) and private sectors

Dale Hamilton Background

- Assistant Professor of Computer Science at Northwest Nazarene University
- M.S. in Computer Science from The University of Montana
- Ph.D. in Computer Science from The University of Idaho
 - Improving Mapping Accuracy of Wildland Fire Effects from Hyperspatial Imagery using Machine Learning*
- 20 years developing wildland fire software for DOI and USFS.

Collaboration Background

- Agreement was signed in Spring 2018
 - Challenge Cost Share Agreement expires 2023
- The purpose of the collaboration is to record historic archaeological landscapes. Including:
 - Mining sites
 - Railroad grades
 - Historic Trails
- Once sites are recorded, NNU is tasked with developing the photogrammetric models and Machine Learning algorithms to locate artifacts and features from the images.

FAA Regulations for Commercial Use

- The Federal Aviation Administration (FAA) regulates the use of all aircraft within United States airspace
- Has special requirements for commercial UAS use under the 'Small UAS Rule' or 'Part 107'
 - Must have a Pilot in Command (PIC) with a Part 107 exemption
 - UAS must be registered with the FAA
 - The UAS must remain in sight at all times
 - UAS cannot fly above 120 meters (400 feet) altitude

FAA Regulations for Non-Commercial Use



- Unless you are working for a company that is getting paid (or you are getting paid) for the UAS data, you would fall under these regulations:
 - Must register UAS with the FAA
 - You do **NOT** need a Part 107 exemption, though this is recommended
 - UAS must remain in sight at all times
 - UAS cannot fly above 120 meters (400 feet)

*Other regulations may exist depending on the State and/or city

** Please consult the FAA website for further information
(<https://www.faa.gov/uas/faqs>)

What UAS Did We Use?

- DJI Phantom 4
 - 12 megapixel camera
 - 15 minutes of flight time per battery
- DJI Inspire
 - 12 megapixel camera
 - 10-12 minutes of flight time per battery



DJI Phantom 4

What UAS Should You Use?

- Buy a small inexpensive UAS until you become familiar with the technology
- There are a lot of good UAS that can be purchased for under \$200.
- “Box stores” have many good starter drones
- Practice, Practice, Practice!!!



How We Collected the Data

- Develop a flight procedures plan
- Have a Pilot-in-command (PIC) and Lead Visual Observer (LVO)
- The LVO stays with the PIC, who flies the UAS
 - The LVO directs all communication/commands between the VOs and PIC via radio
 - Commands might include: “Taking off”, “At altitude”, any directional changes (“Going north”, etc.), “Landed”.
- Visual observers (VOs) spread out across the project area to a designated location
 - Hill top, road, clearing, etc. (need to be able to see the sky/UAS)
- VOs respond to LVO when they can see the UAS and when they lose sight of the UAS

Definitions:

- **Orthomosaic** – is a georeferenced two dimensional (2D) model stitched together from aerial images to create a complete picture of the recorded landscape.
- **3D Model** – is a model generated by stitching together georeferenced images through an algorithm called 'Structure from Motion'. It is an accurate representation of the landscape on all three axis.
- **Machine learning** – is a method of data analysis that automates analytical model building. It is a branch of artificial intelligence based on the idea that systems can learn from data, identify patterns and make decisions with minimal human intervention.

How Does Machine Learning Work?

- Users collect imagery (training images) which include objects that we want an artificial intelligence (AI) to be able to find in other images.
- Users identify a set of known objects in the training image, associating training labels with known objects.
 - burn/unburned, road (rail grade), foundation, can scatter
- AI builds model that allows it to identify objects similar to labeled training objects.
- Run AI on drone orthomosaic, identifying previously unidentified objects similar to training objects.

Labeling Training Data

FireMAP

Training Data Selector

About FireMAP | Imagery | Reports | Training Data Selector

Save Undo Redo

Tool Selector

Point Pencil

Line PolyLine

Polygon Circle

Auto-Cluster Flood Fill

Label

Showing: All Labels

(187,754) (1400,787)

Coordinates(x,y) Dimension(x,y)

Shift-Scroll to resize image.

Delete Load

Color Picker

Insert Color Wheel here

Tutorial

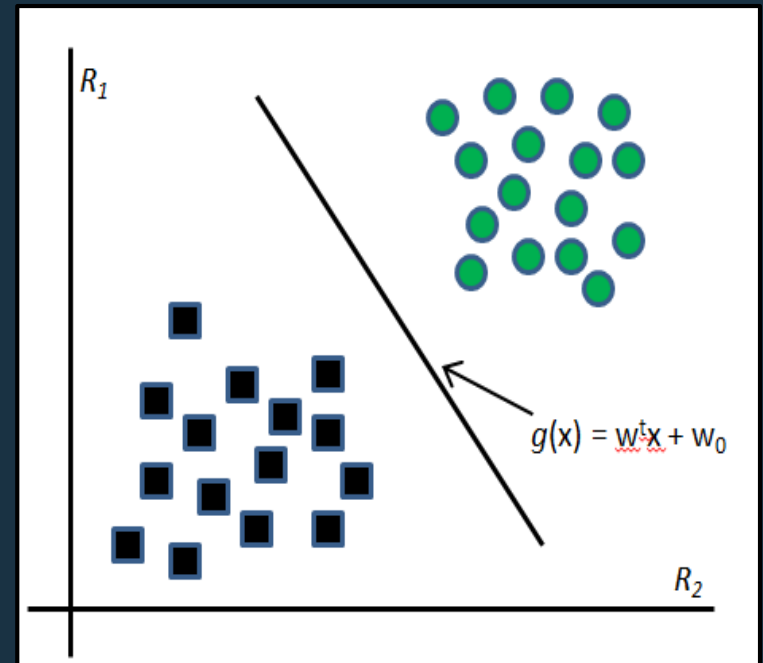
Select Training Image

Training Data Selector

Building the Model

Machine learning for image classification

- Supervised Classification
 - Learn by example
 - Support Vector Machine
 - Decision Tree
 - Convolutional Neural Network



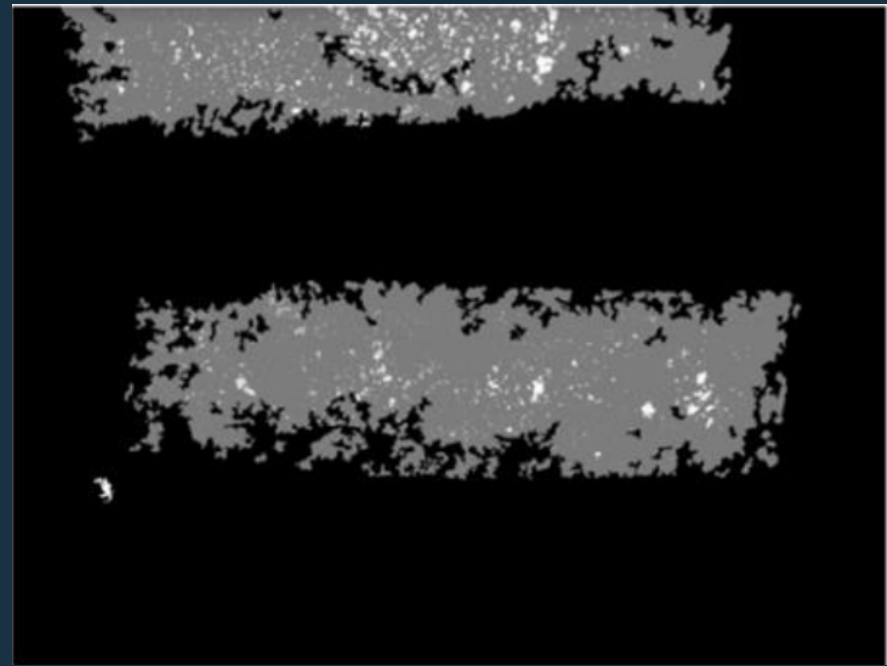
Support Vector Machine (SVM)

What can the computer see?

Burn extent and severity



sUAS burn image from 120m AGL



Burn Extent/Severity Classification

Black => unburned

Gray => low consumption

White => high consumption

How do UAS Help Record Historic Trails?

- UAS can acquire high resolution images
- Images can help with Trail Recognition (even without generating photogrammetric models)
- Images allow a “birds eye view” to see things that cannot always be seen standing on the ground
- UAS and Machine Learning can help identify a ‘Trail Corridor’
- Look for:
 - Changes in vegetation
 - More vegetation or less vegetation in a certain area
 - White or brown lines
 - Changes in shadows (could indicate a swale or depression)

Oregon Trail

- Recorded three miles of trail
 - One mile burned, two miles unburned
 - Wanted to see if it was easier/harder to locate the trail in a burned or unburned area
- NNU developed an algorithm that can locate linear features

Oregon Trail (cont.)



Orthomosaic of a three mile section of the Oregon Trail.



Oregon Trail
1:300 Scale

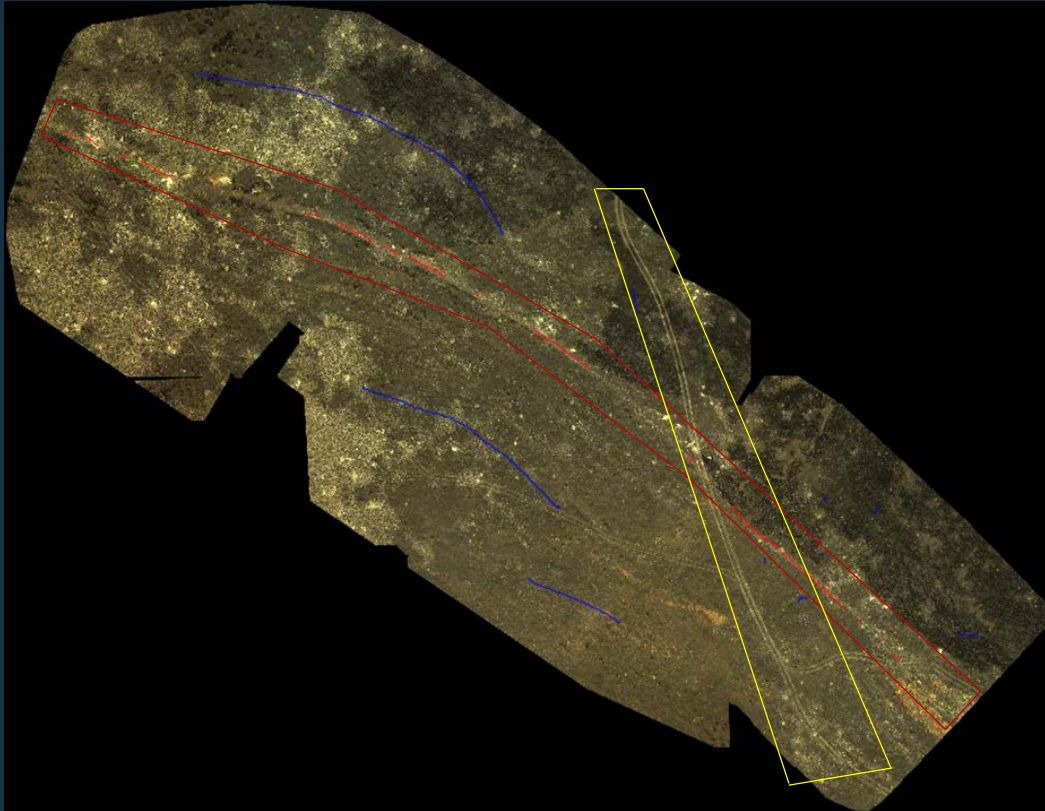


Oregon Trail
1:200 Scale



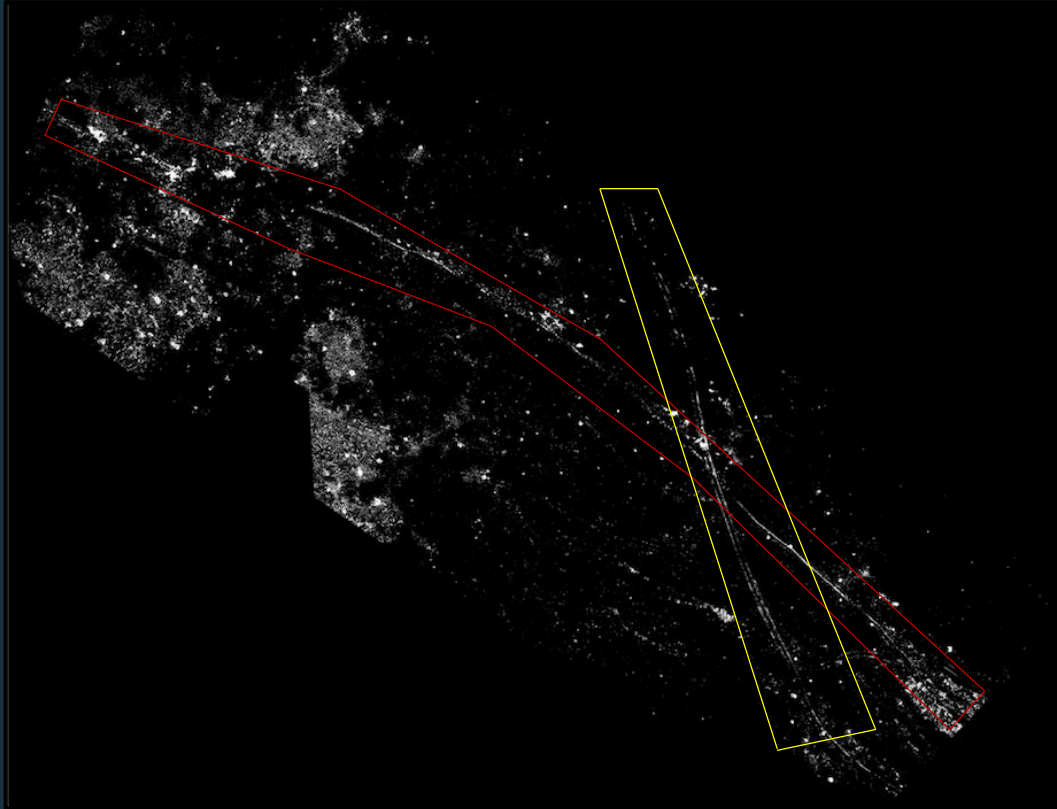
Oregon Trail
1:200 Scale

Oregon Trail (cont.)



- This is a one mile section Of the Oregon Trail that burned in 2017.
- The red box indicates the Oregon Trail. The yellow box shows a road.
- Image has 5cm spatial resolution

Oregon Trail (cont.)



- This is a classified image of slide 18.
- The Machine Learning algorithm determined that the white is a linear feature and the black is not.
- The red box shows the Oregon Trail, and the yellow box shows a road.

How do UAS Help Record Other Archaeological Sites?

- UAS can acquire high resolution images
- Images can help with artifact/feature recognition (even without generating photogrammetric models)
- Images allow a “birds eye view” to see things that cannot always be seen standing on the ground
- Speed:
 - Able to record over 200 acres an hour
 - Average archaeologist can record 100 acres through pedestrian survey in a 10 hour day
- Allow easy access into hard to reach places

Other Archaeological Sites Recorded in 2018

- Historic Mining
 - Over 3,500 acres of mining landscapes
 - Four historic Chinese and/or Euro-American mining sites
- Historic Railroad
 - Over 2.5 miles of Historic Railroad grade

Intermountain Railroad

The Intermountain Railroad was in use in the early 20th century. Its primary function was to bring timber and ore from the Boise Basin to the Treasure Valley. The track was removed in the 1930s.



Intermountain Railroad grade
The grade is shown in the red box.
Scale 1:200

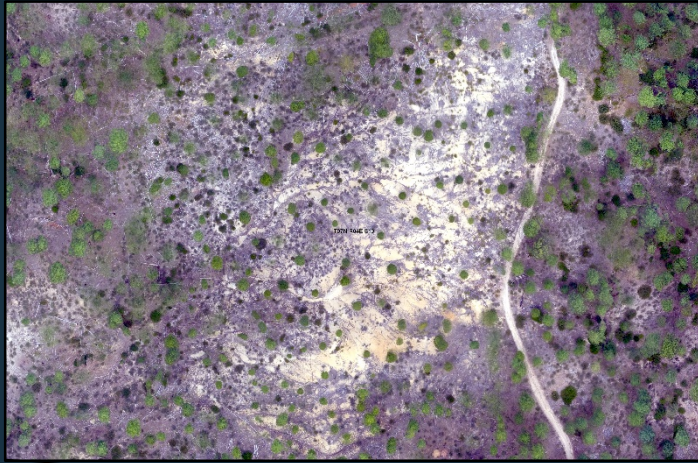
Intermountain Railroad (cont.)



An image taken from the orthomosaic of the Intermountain Railroad grade. The grade is shown in the red box.

Scale 1:150

Historic Mining

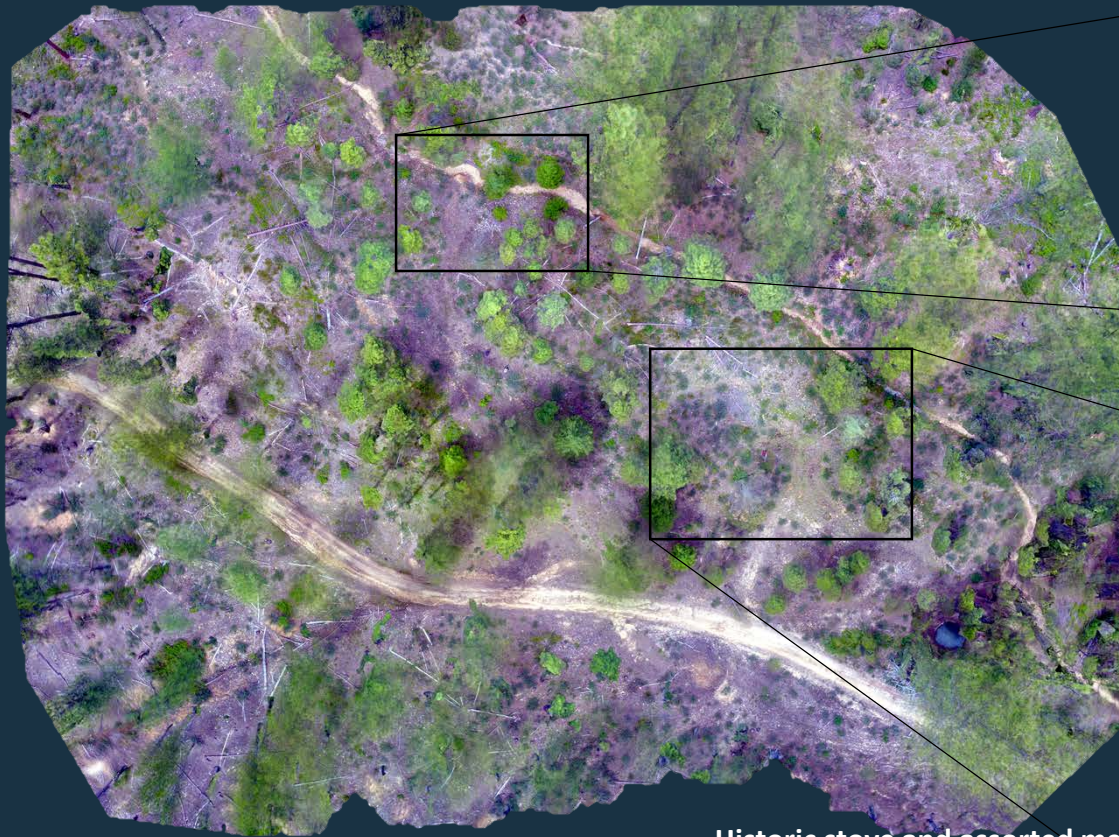


Historic Hydraulic Mining
Scale 1:500



0.75 miles

Chinese Mining Site



Hand-stacked tailings
Scale 1:80



Historic stove and assorted metal
Scale 1:100

Mine Tailings Classifier



Mine Tailings that have been classified by the Machine Learning algorithm. The green box shows the classified mine tailings.



Road Detection Classification



Roads (linear features) that have been classified by the Machine Learning algorithm. The green box shows the roads.

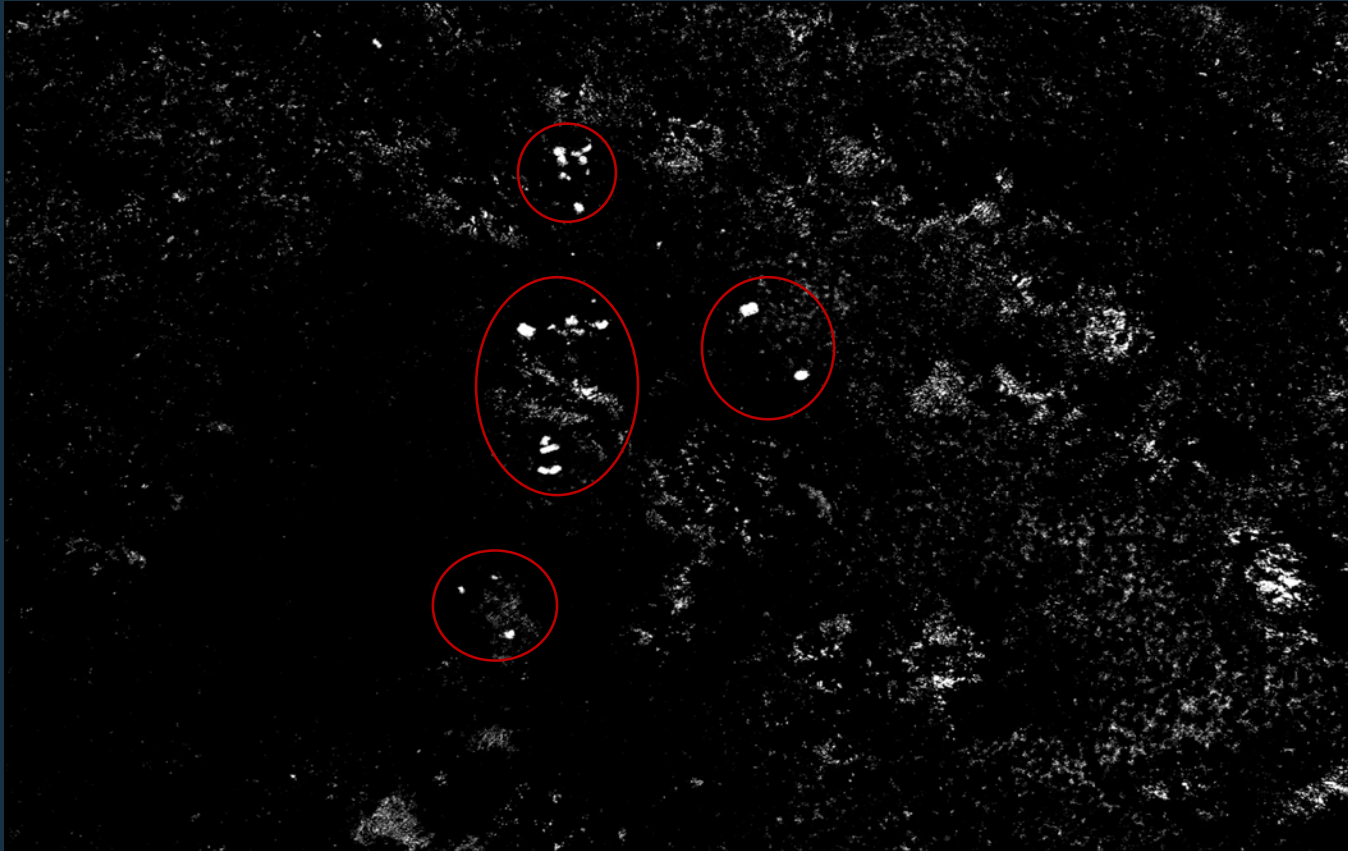


Can Scatter



Image of a Can Scatter taken from a UAS. The location of the cans is circled in red.

Can Scatter (cont.)



This is a classified image of Slide 28. The cans are shown as white spots and the surrounding landscape is black. The cans are circled in red. The algorithm has a 96.854% confidence that it identified all of the cans in this image.

What Have We Learned?

- Best practices:
 - Record at 120 meters altitude for landscapes
 - Record at 40-50 meters altitude for sites
 - Began building a methodology and precedents for how to collect the data
 - We can locate historic trails, historic cans (metal), roads, and mine tailings directly from the orthomosaics with Machine Learning
- Learning experiences:
 - Know previous flight area (models) prior to flying an adjacent area to prevent excessive overlap
 - DEMs are not substantially more accurate with the use of a GPS ground station

Future Plans

- Agreement has been funded for Summer 2019
- Plan to work on/finish algorithms over the winter
- In 2019 we want to record the data, and within 24 hours be examining the data
 - Photogrammetric 3D/2D models and all four algorithms
 - This will help us potentially identify all types of sites, including trails, railroad grades, and historic scatters
- We want to record a minimum of 4,000 acres
- We will experiment with multispectral (near infrared) imagery
- Record structures

Contact Information

- Please contact Adam Calkins or Dale Hamilton with any questions regarding this presentation
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