LA-UR-15-27039

Title: Surface Signature Characterization at SPE through Ground-Proximal Methods: Methodology Change and Technical Justification

Author(s): Schultz-Fellenz, Emily S.

Intended for: SPE Test Management Team Review and quarterly reporting

Issued: 2015-09-09

Surface Signature Characterization at SPE through Ground-Proximal Methods: Methodology Change and Technical Justification

Emily S. Schultz-Fellenz
Principal Investigator
Los Alamos National Laboratory

A portion of LANL's FY15 SPE objectives includes initial ground-based or ground-proximal investigations at the SPE Phase 2 site. The area of interest is the U2ez location in Yucca Flat. This collection serves as a baseline for discrimination of surface features and acquisition of topographic signatures prior to any development or pre-shot activities associated with SPE Phase 2. Our team originally intended to perform our field investigations using previously vetted ground-based (GB) LIDAR methodologies. However, the extended proposed timeframe of the GB LIDAR data collection, and associated data processing time and delivery date, were unacceptable. After technical consultation and careful literature research, LANL identified an alternative methodology to achieve our technical objectives and fully support critical model parameterization. Very-low-altitude unmanned aerial systems (UAS) photogrammetry appeared to satisfy our objectives in lieu of GB LIDAR. The SPE Phase 2 baseline collection was used as a test of this UAS photogrammetric methodology.

From July 28-30, 2015, LANL deployed a team to NNSS to collect Structure-from-Motion (SfM) (Bemis et al., 2014) photogrammetric data, herein referred to as UAS photogrammetry, from a very-low-altitude UAS platform (a DJI Inspire 1 quadcopter drone) using its standard onboard 12-megapixel still camera payload. The field team consisted of LANL staff and subcontract technical support from Coppersmith Consulting, Inc. (CCI) of Walnut Creek, CA. A map of the field area and collection landmarks is attached to this document (Figures 1 and 2). The area is broken into two collection regions, defined as follows:

> (1) one high-resolution region near the emplacement hole (Figure 1). In this region, exceptionally high-resolution data was favored over extensive spatial coverage. In this region, a professional surveyor with expertise in ground control for LIDAR and photogrammetric studies installed a 10m grid of ground control points (GCP) in a 100m x 150m area. The UAS photogrammetry data was collected at approximately 5-7 m above ground level (AGL). This collection focused specifically on the U2ez emplacement hole region, as we anticipate this area will most likely incur surface change as a result of SPE Phase 2 shots and activities.
>
> (2) one lower-resolution site-wide region (Figure 2). Here, areal extent was favored over high-resolution, but allowed testing of resolution satisfaction. In this region, a surveyor installed a 50m grid of GCP targets in a 300m x 400m area, and UAS photogrammetry data was collected at approximately 30-40m

AGL. This collection was designed to capture both the high-resolution region (for comparison purposes) and a greater surrounding region, including the U2ay collapse crater east of U2ez.

The very-low-altitude UAS photogrammetric study was largely executed as scoped. A total of 1,885 overlapping photos were captured in the high-resolution study area. The high (75-90%) overlap ratio at an average of 7.5m flying altitude resulted in a very dense point cloud (28,000 points/m^2), a ground resolution of 2mm per pixel, and a 5mm digital elevation model (DEM). In the lower-resolution study area, a total of 1,018 overlapping photos were captured at an average altitude of 38m. The dense point cloud generated from these photos resulted in 1,275 points/m^2, a ground resolution of 1.4cm per pixel, and a 2.8cm DEM. Strategic ground survey control was established using real-time kinematic GPS techniques to provide geometric optimization and spatial georeferencing for the point clouds. This process employed 13 ground control points from the high-resolution study area and 19 from the lower-resolution study area. The precise survey control utilized on-site resulted in sub-centimeter horizontal and approximately 1.5cm vertical resolution for the 3D models. Preliminary data was delivered on August 10, 2015; all raw and processed data, as well as DEMs, were completed and delivered on August 27, 2015.

While we have not yet collected UAS photogrammetric data in a region where our GB LIDAR datasets exist (this shall happen and fieldwork is in the planning stages), a direct comparison of resolution in identical datasets cannot be completed at this time. However, it appears that the lower-resolution photogrammetry dataset is roughly equivalent in resolution (~2cm grid size) to existing GB LIDAR data from NCNS projects at NNSS (Schultz-Fellenz et al., 2013). The point cloud distribution from the photogrammetry set is more evenly distributed across the area, largely due to the fact that the sensor is nadir to its target and therefore less susceptible to shadowing and blocking by vegetation (an undesirable feature observed in the GB LIDAR dataset). In addition, the photogrammetry data provides RGB color information that is incorporated into the point cloud data, which is a distinct advantage over GB LIDAR in mapping surficial geology and deformation features. Another significant difference between the two datasets is that the UAS photogrammetry does not require artificial removal of points associated with survey equipment (e.g., manual dataset removal of tripods, persons passing through an active scan region) at numerous locations across the survey area. Thus, the UAS photogrammetry yield a much more pristine dataset and minimizes the risk of loss or degradation of important data within the inspection area. The result is a smoother DEM surface that is easier to interpret.

The photogrammetrically-generated LAS files of the lower-resolution region have been processed within ArcGIS, and produced a DEM at a 2cm grid size with very few dropouts or data gaps. Figure 3 shows this DEM. LANL is currently processing the high-resolution photogrammetrically-generated LAS dataset to produce a 2mm grid size DEM, which would exceed the grid size of GB LIDAR by a factor of ten. CCI data processing and

LANL/CCI analyses have confirmed through a preliminary deliverable to LANL that the data quality of the high-resolution study area exceeds the resolution of previous GB LIDAR data collections in support of NCNS at NNSS. **This team therefore notes that our very-low-altitude UAS photogrammetric method meets or exceeds anticipated data quality expectations, and justifies that UAS photogrammetry and its data products are equivalent, if not superior to, previously employed GB LIDAR methods in support of NCNS objectives. We therefore request to officially change this SPE diagnostic method to our very-low-altitude UAS photogrammetry method.**

We wish to acknowledge some specific use parameters of our very-low-altitude UAS photogrammetry methodology, particularly for time-sensitive efforts like SPE shots. Use of UAS photogrammetry at NNSS is contingent on the availability of our supporting pilot, a LANL employee with FAA drone operation certification who also has other programmatic obligations. Operations are also contingent on approval by NSTec airspace deconfliction personnel. The collection can proceed when weather and lighting conditions are favorable (e.g., winds below 15mph/13kts, no precipitation, not full direct midday lighting which can wash out photo frames). Morning and afternoon-to evening lighting permits satisfactory collection, and flat lighting (full cloud cover) is ideal. The success of high-resolution, real-world data hinges also on the involvement of a professional surveyor with expertise in ground control for detailed surface characterization studies like these. Once survey ground control is installed, two persons are required for drone operation (master (flight) and slave (camera) controls), and a support person accompanies the team to document the collection, replenish batteries and camera memory cards, and help quality-check data as it is downloaded.

References:

Bemis, SP, S Micklethwaite, D Turner, MR James, S Akciz, S Thiele, and HA Bangash (2014). Ground-based and UAV-based photogrammetry: a multi-scale mapping tool for structural geology and paleoseismology. *Journal of Structural Geology* **69**, 163-178.

Schultz-Fellenz, ES, AJ Sussman, RE Kelley, and D Cooper (2013). Post-shot surface damage detected with LIDAR at the Source Physics Experiment site. Abstract S31E-04 presented at the 2013 Fall Meeting of the American Geophysical Union, San Francisco, California, 9-13 December.

Figure 1.

High Resolution-First Priority Location

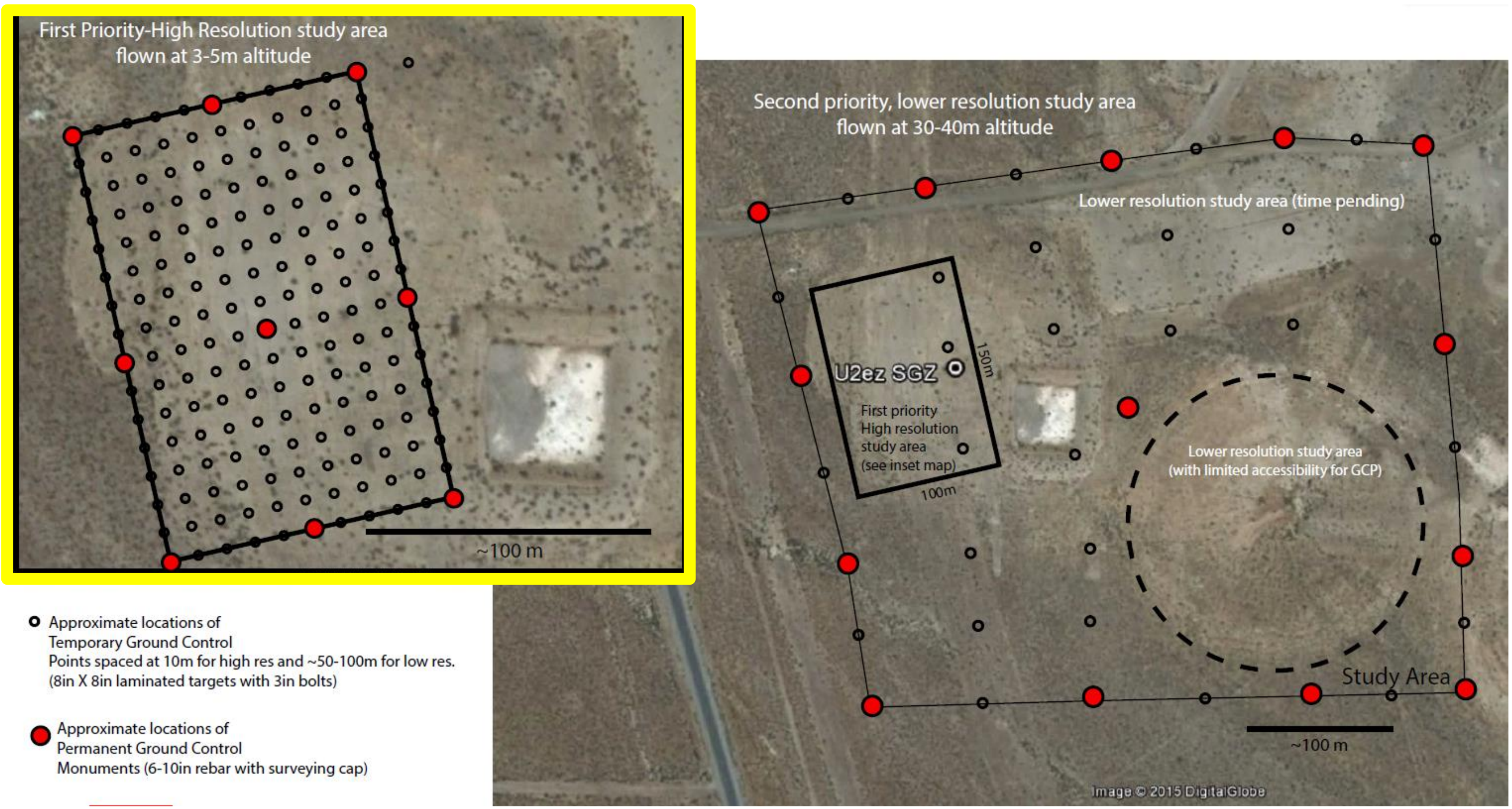


Figure 2.

Low Resolution-First Priority Locations

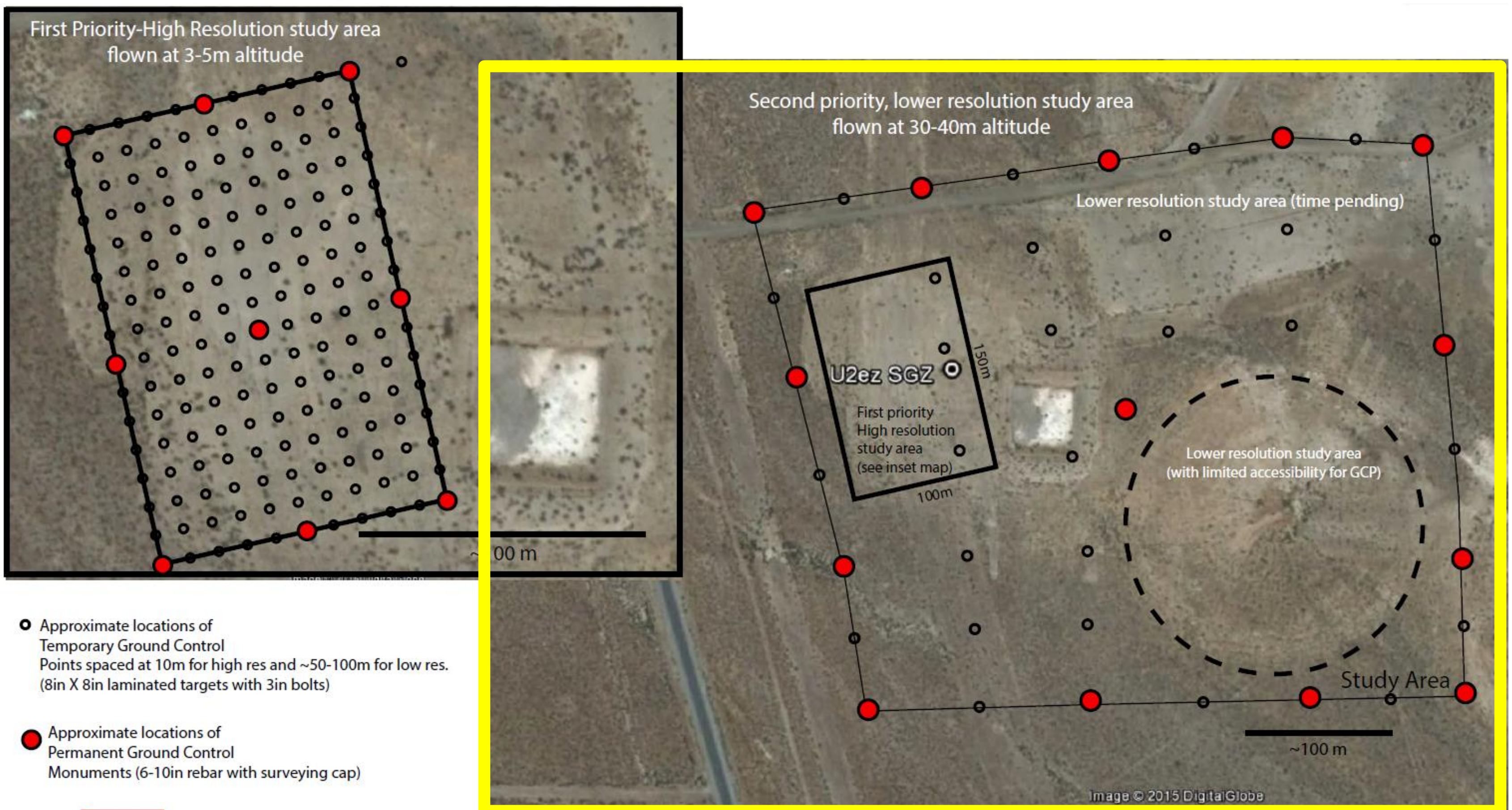
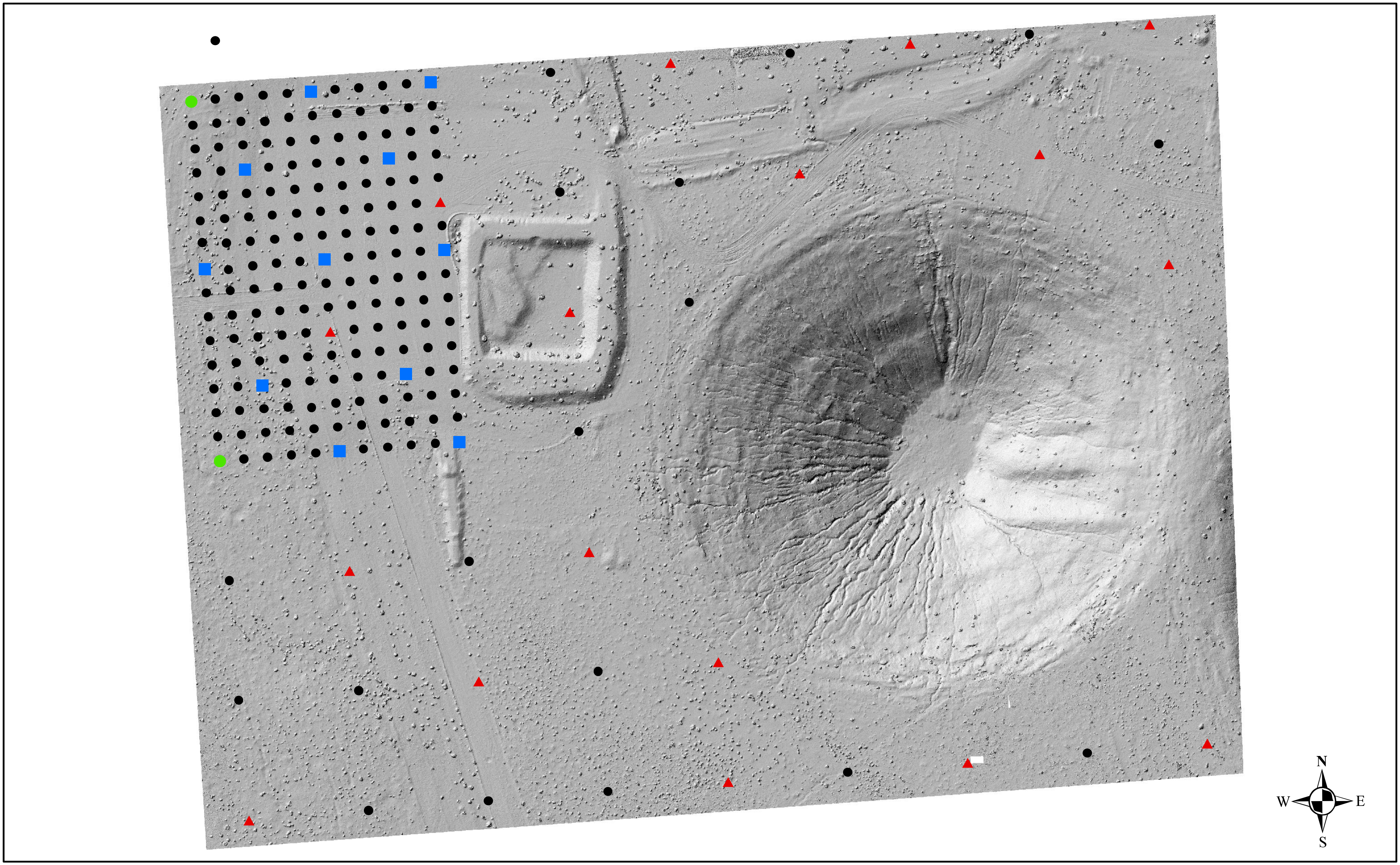


Figure 3.



Legend

U2ez Survey Data

- GCP Targets and Control Points
- Survey Points Used for High Res Study Area
- Survey Points Used for Low Res Study Area
- Survey Points Used in Both Study Areas

0 20 40 80 120 160

Meters

Coordinate system: NAD83_UTM_zone_11N
Vertical Datum: NAVD88

Coppersmith Consulting Incorporated