Subsurface, Surface, and Remote Observations of Legacy Nuclear Explosion Sites

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T3.3-P8

Objectives

-Develop capabilities for remotely detecting and analyzing underground nuclear explosion (UNE) signatures and observables.

-Develop UNE site location and characterization methodology.

-Provide ground truth for UNE models and simulation

What	How	Extent	Resolution
WV-3 VNIR, SWIR, PAN	Satellite	100 km²	0.3 m Pan, 1.2 m VNIR (8 bands), 7.5 m SWIR (8 bands)
HSI	Airborne	3.3 km²	10 cm spatial, 2.2 nm spectral
HSI	Ground based	450 point measurements	3 nm VNIR, 8 nm SWIR
RGB Photogrammetry	Airborne	4.5 km²	2.5 cm
LIDAR	Airborne	7 km²	3.25 cm
LIDAR	Ground based	0.14 km²	3 mm
Geologic mapping, gravity, magnetics	Ground based	0.53 km²	3 m
X-Band SAR	Satellite	100 km²	1 m
X-band fully polarimetric SAR	Airborne	1.2 km²	0.1 m
Ku-band SAR	Airborne	1.2 km²	0.1 m

U20az and U20ak are sites of nuclear explosive tests at the NNSS that took place in 1989 and 1985, respectively.

Status

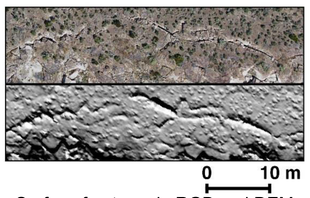
-All planned test bed (U20az/ak) collections complete.

-Multiple technologies and scales allow for characterization of diverse observables:

- Geological surface features
- Cultural artifacts
- Vegetation signatures

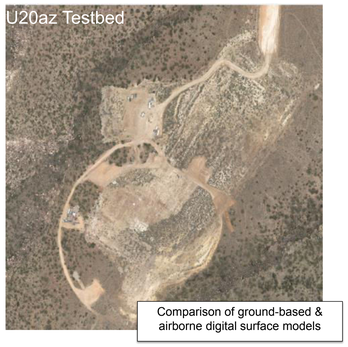
-Observables enhance UNE site location and identification.

Silent Falcon UAS Platform.



Surface fractures in RGB and DEM

DEM	Horizontal Accuracy (m)	Vertical Accuracy (m)	GSD (m)
LIDAR	0.072 ± 0.042	0.027 ± 0.014	0.125
Photogrammetry	0.203 ± 0.054	0.119 ± 0.02	0.05



Comparison of ground-based & airborne digital surface models

A DeHavilland Twin Otter (DHC-6) is used to fly the FARAR Ku-Band SNL SAR.

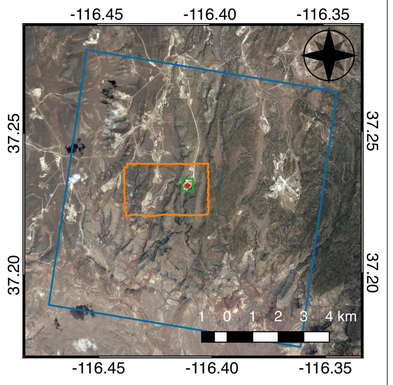
Approach

-Integration of ground-air-space technologies:

- Light Detection and Ranging (LIDAR)
- Synthetic Aperture Radar (SAR)
- Multispectral Imagery (MSI)
- Hyperspectral Imagery (HSI)
- Multi-modal ground truth campaigns

U20az Collections			
Technology	Ground	Air	Space
Imagery	X	X	X
Spectral	X	X	X
LIDAR	X	X	
SAR		X	X

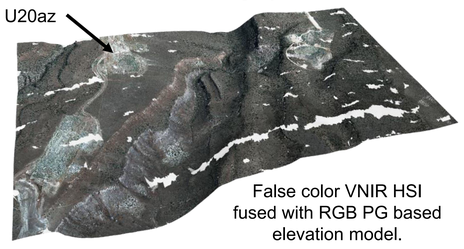
- Aqueduct/Barnwell (U20az)
- Groud-based LIDAR
- Airborne LIDAR
- Satellite SAR



Airborne Optical and LIDAR

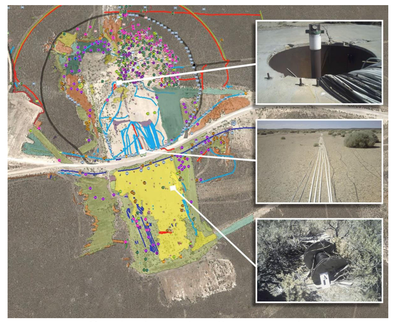
-LIDAR, RGB Photogrammetry (PG), and VNIR Hyperspectral Imagery collected over 4 km² from manned and unmanned platforms.

- Low altitude unmanned systems allow for both high spatial resolution and large collection extent.
- Photogrammetry elevation products have comparable relative accuracy to LIDAR for much less cost and complexity.
- High resolution context RGB imagery is valuable for fusing modalities.



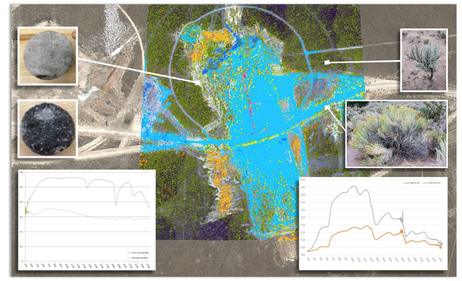
False color VNIR HSI fused with RGB PG based elevation model.

Ground-Based Surface and Subsurface Measurements

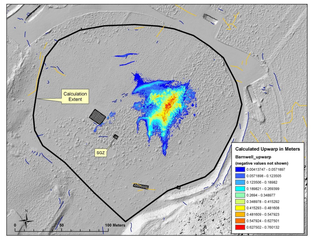


Geologic and anthropogenic artifact/anomaly mapping

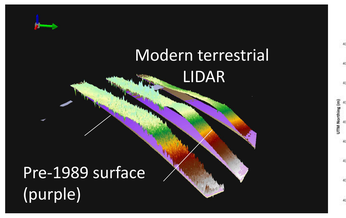
- Identifies activities at a location of interest
- Reduces uncertainty in location identification
- Provides essential ground truth for remote platforms
- Quantifies surface damage
- Images subsurface anomalies



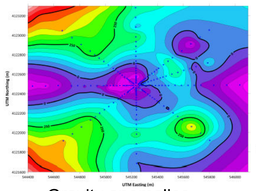
Surface verification of multispectral signatures (geologic, vegetative, anthropogenic)



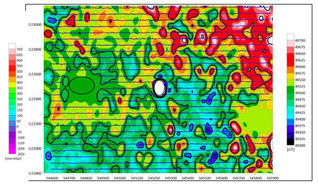
Digital Elevation Model Δz



Cross-sectional Comparison: Projected pre-1989 surface vs. modern terrestrial LIDAR



Gravity anomalies



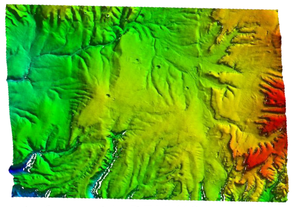
Magnetic anomalies

Satellite and Airborne SAR

Explore the utility of synthetic aperture RADAR (SAR) to characterize surface signatures of an underground nuclear explosion by exploiting existing methods and developing new SAR exploitation algorithms and collection strategies

Satellite SAR at U20az

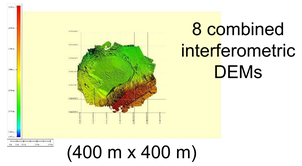
- COSMO SkyMed
- 1-m ground resolution
- Better satellite SAR resolutions being fielded



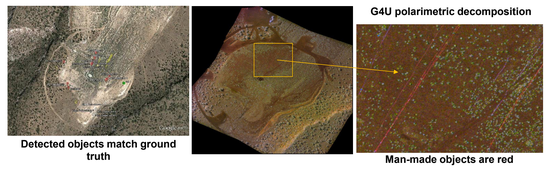
Interferometric DEM (10 km x 10 km)

Airborne VideoSAR at U20az

- Fully-polarimetric SAR
- 4” ground resolution
- Digital Elevation Maps (DEMs)
- Detection of man-made objects
- SAR is an all-weather, day/night sensor.



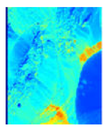
(400 m x 400 m)

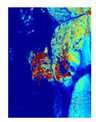


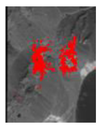
Detected objects match ground truth

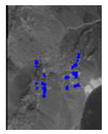
Man-made objects are red

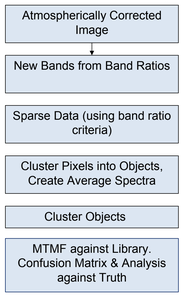
Algorithm Development











Future work: second test bed

Completed Collections:

SAR (airborne and space)

Initial World View 3 MSI

Planned Collections:

Additional World View 3 MSI

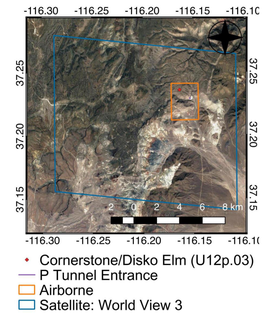
Airborne photogrammetry, hyperspectral imagery (VNIR and SWIR)

Targeted low-altitude UAS photogrammetry

Ground-based geologic, cultural, and vegetative mapping and reference spectra

Planned Analysis:

Algorithm development for signature extraction across modalities and scales



Cornerstone/Disko Elm (U12p.03)
P Tunnel Entrance
Airborne
Satellite: World View 3

The Underground Nuclear Explosion Signatures Experiment (UNESE) was created to apply a broad range of research and development (R&D) techniques and technologies to nuclear explosion monitoring and nuclear nonproliferation. It is a multi-year research and development project sponsored by NNSA DNN R&D, and is collaboratively executed by Lawrence Livermore National Laboratory, Los Alamos National Laboratory, National Security Technologies, Pacific Northwest National Laboratory, and Sandia National Laboratories. The views expressed here do not necessarily reflect the views of the United States Government, the United States Department of Energy, the National Nuclear Security Administration, Los Alamos National Laboratory, National Security Technologies, or Sandia National Laboratories. The authors are grateful for the opportunity to work on this project. LA-UR-17-23998