Image Registration and Change Detection for Artifact Detection in Remote Sensing Imagery

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Why do change detection for treaty support?

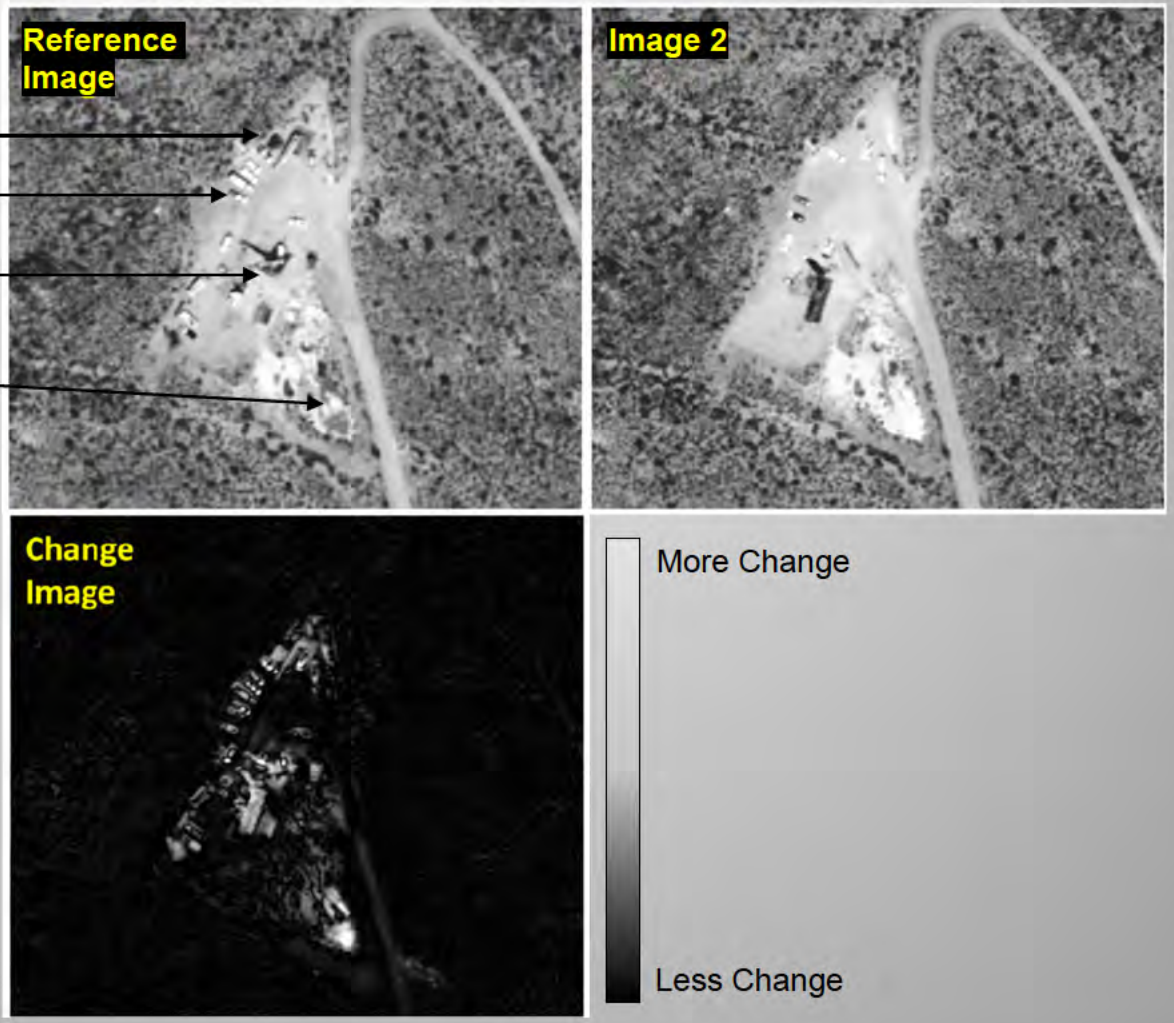
Observables

Construction equipment

Vehicles

Drilling equipment

Mine tailings



*Source Physics Experiment 2 (SPE-2) involves chemical explosions

Summary

Goals:

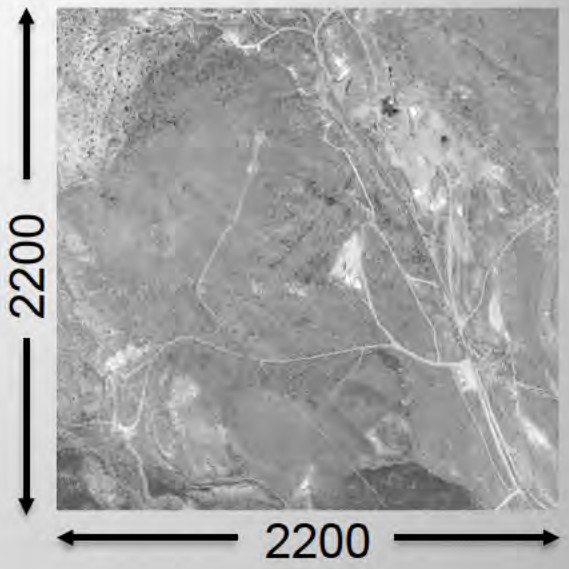
- Produce an image registration algorithm that is suitable for pixel-level change detection
- Must be capable of functioning in mountainous terrain (**non-rigid**)
- Must function with imagery that has a large Δview angle
- Must be easy to implement.
- Must use publicly available programming language
  - Python: numpy, scipy, SIFT, openCV
- Demonstrate on DigitalGlobe data

Targeted Users:

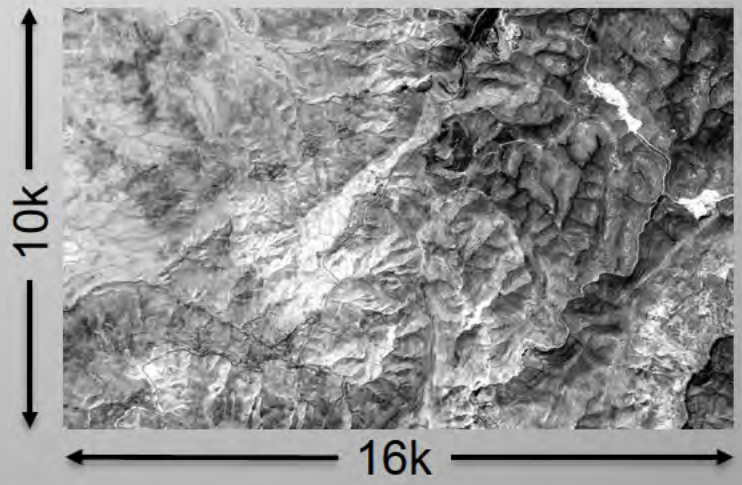
- On-site inspection teams for nuclear arms treaty verification
- Users needing a simple but robust image registration algorithm

Datasets

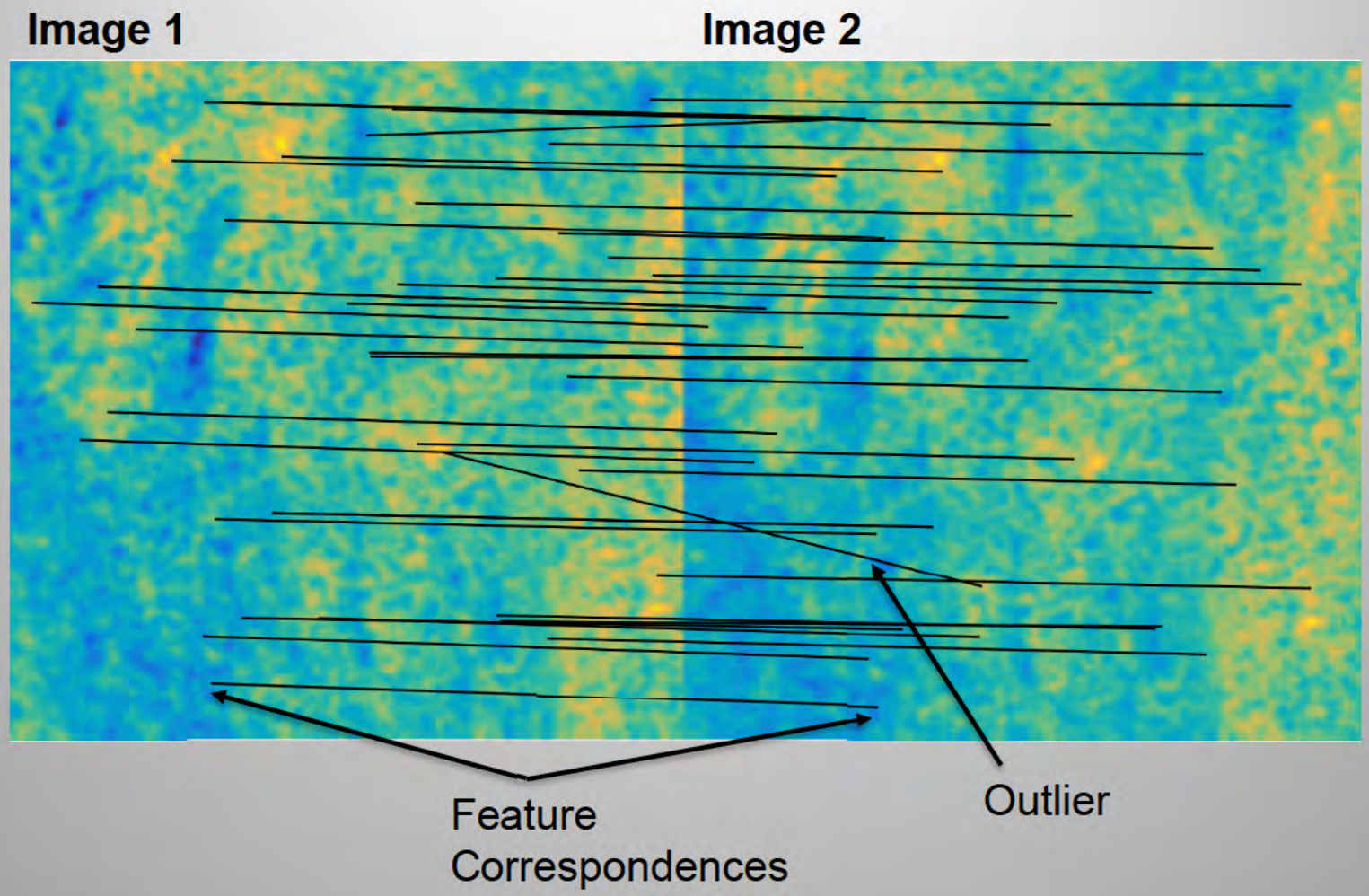
Nevada National Security Site
Sensor: Worldview-II
Orthorectified: 1:4800 mapping accuracy
Terrain: Mountain desert
Dates, Mean Off-Nadir View Angle:
Sept. 2, 2011, 8.3º
Jun. 15, 2011, 12.6º
Δview angle = 6.90º



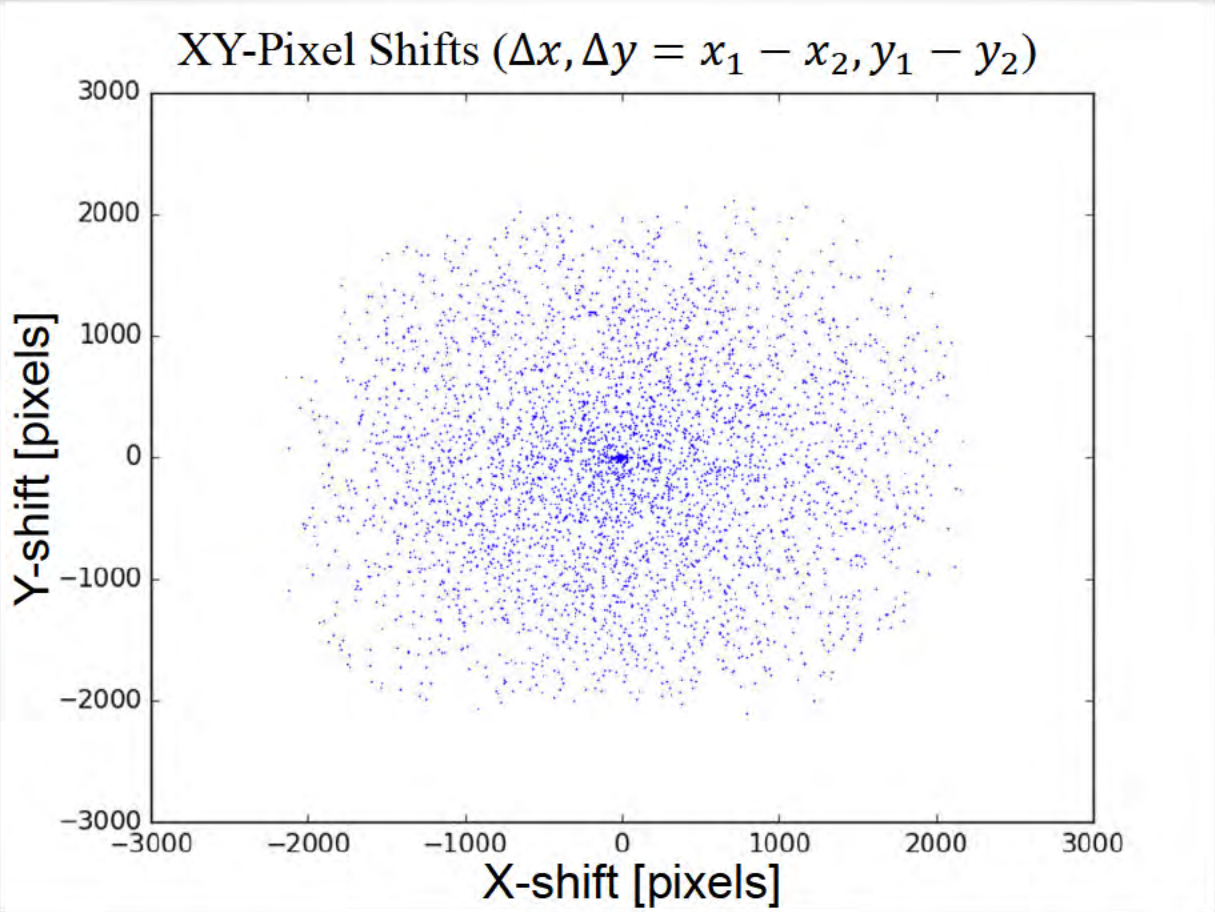
Jordan Site
Sensor: Worldview-II
Geo-registered
Terrain: Mountain desert
Dates, Mean Off-Nadir View Angle:
Feb. 23, 2011, 13.0º
Sept. 27, 2014, 34.3º
Δview angle = 40.9º



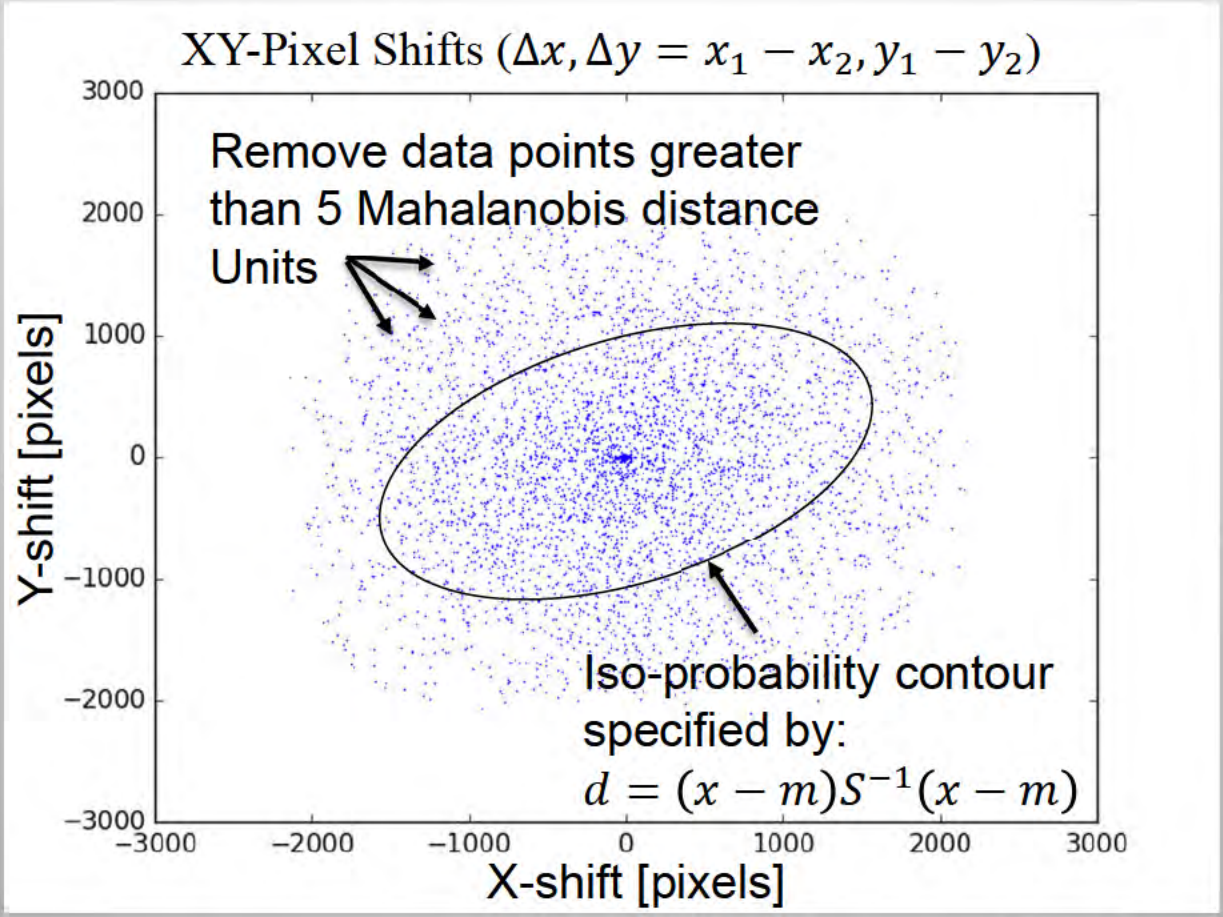
Scale Invariant Feature Transform - SIFT



Iterative Mahalanobis Outlier Rejection (iMOR)

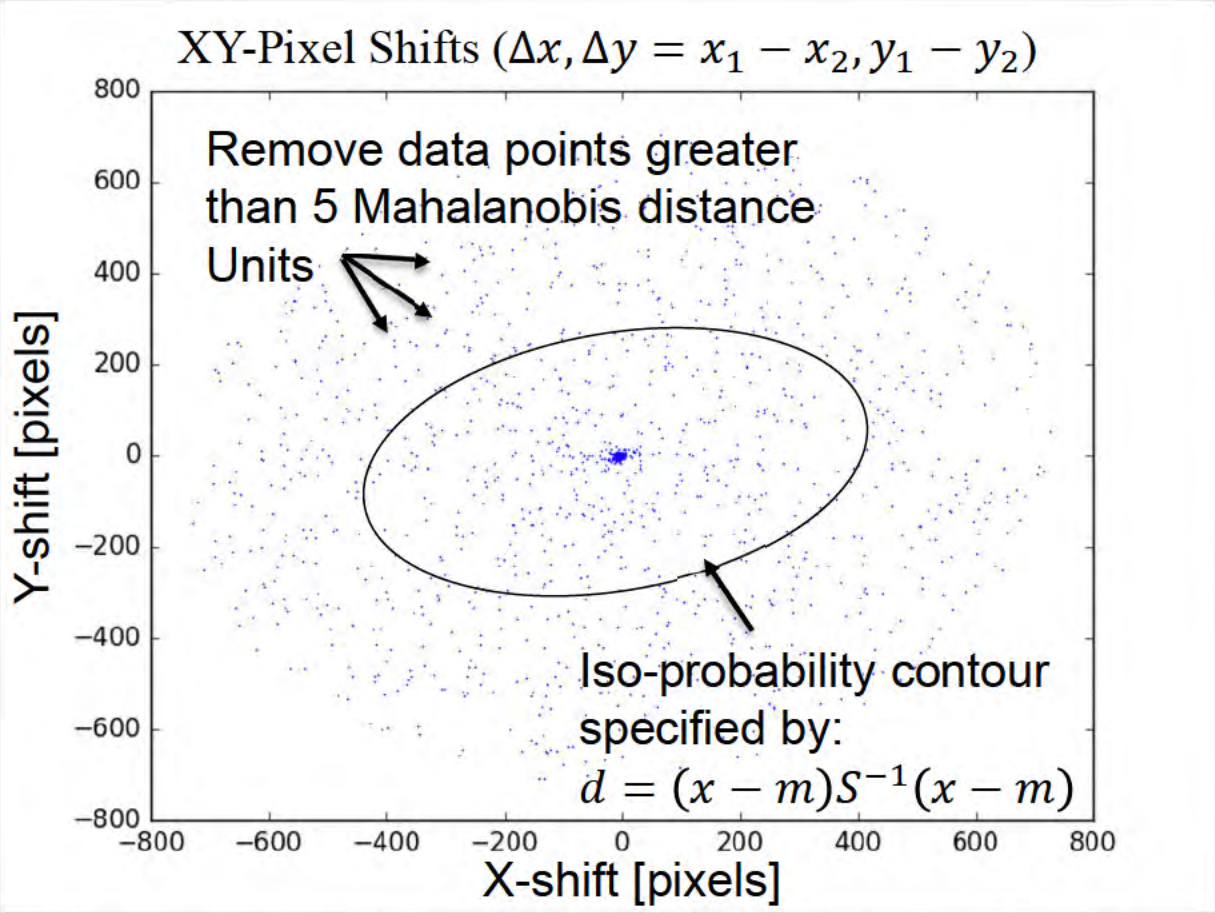


Iterative Mahalanobis Outlier Rejection (iMOR)



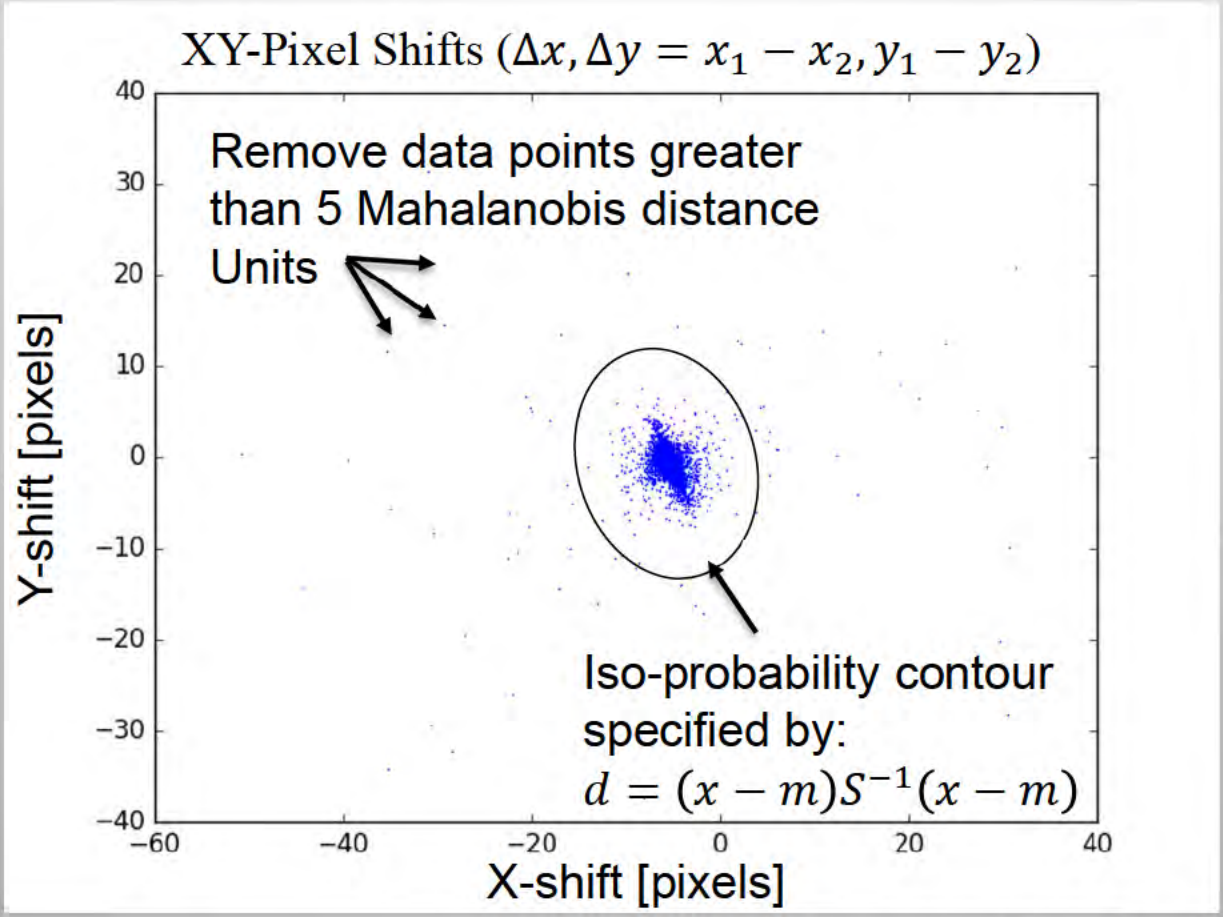
Iteration 1

Iterative Mahalanobis Outlier Rejection (iMOR)



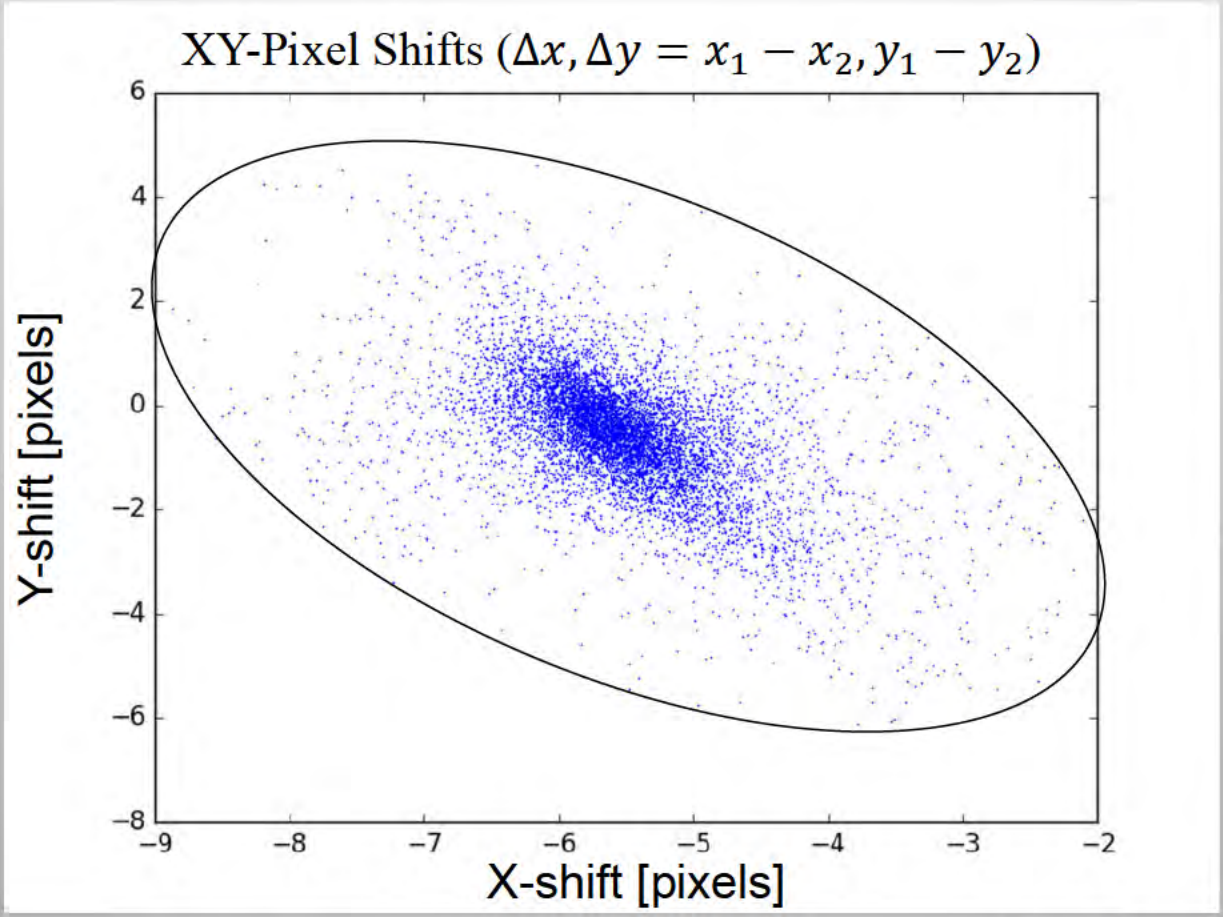
Iteration 7

Iterative Mahalanobis Outlier Rejection (iMOR)



Iteration 9

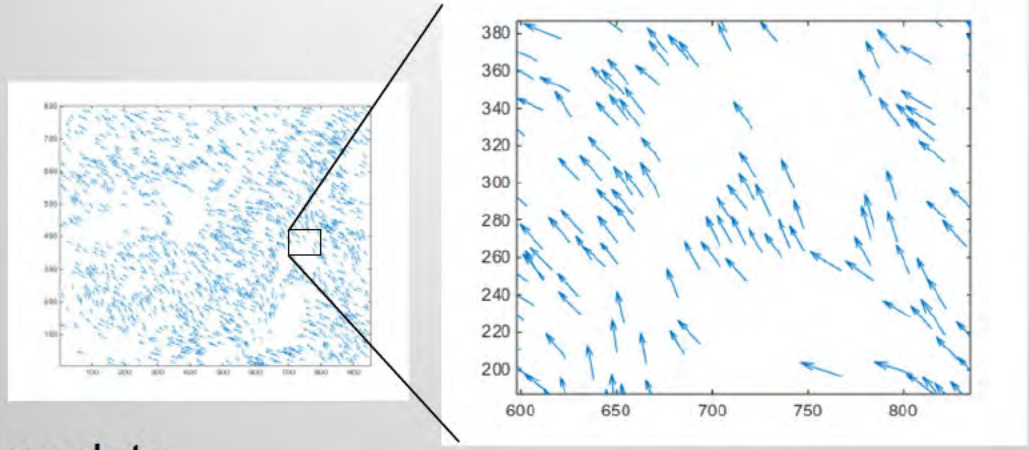
Iterative Mahalanobis Outlier Rejection (iMOR)



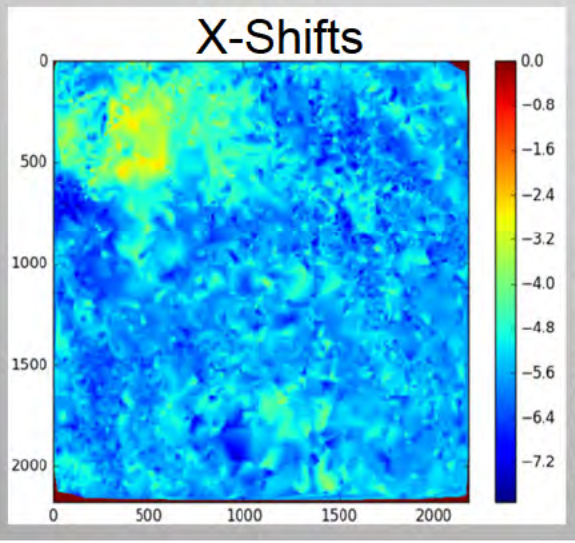
Iteration 17

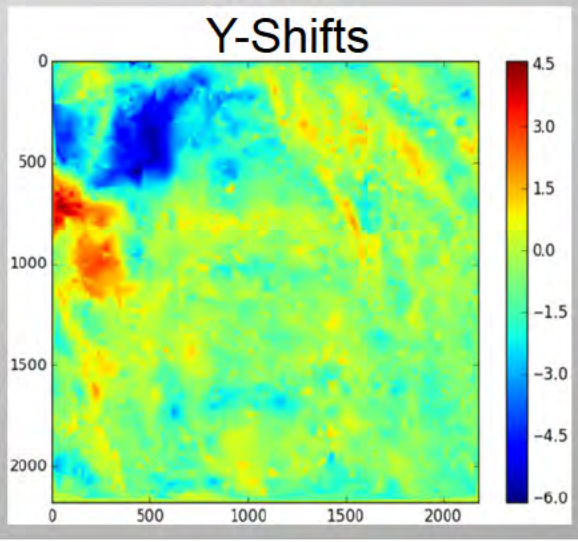
Warping Map Using Robust Feature Correspondences

Quiver Plot Showing Pixel Shifts

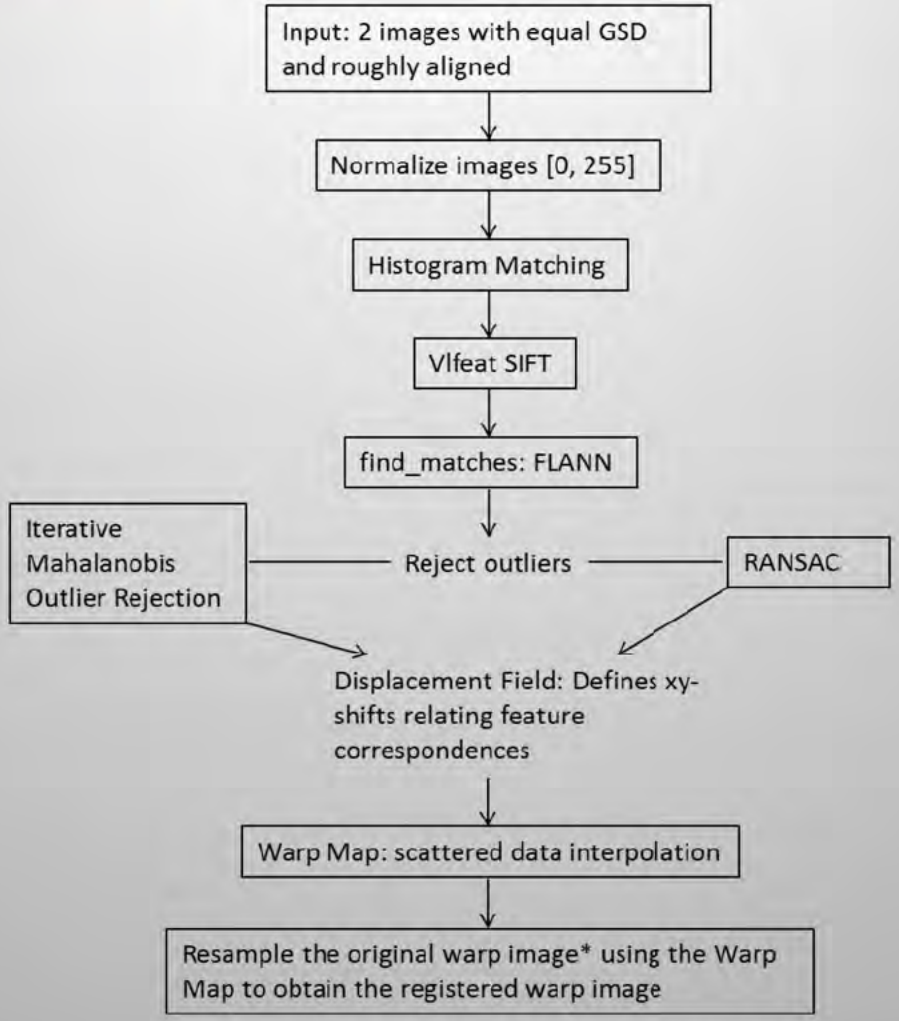


interpolate



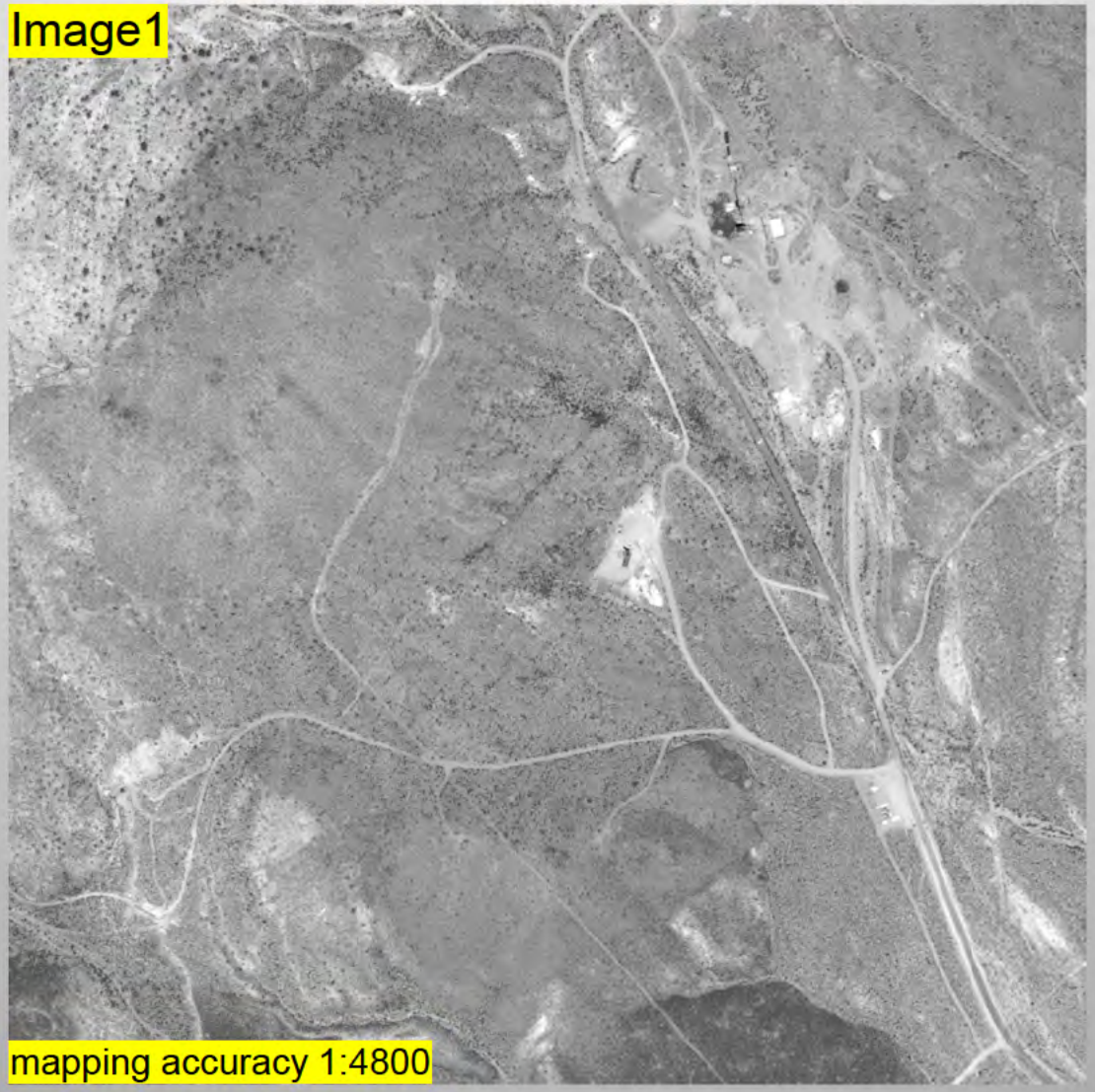


Algorithm Summary

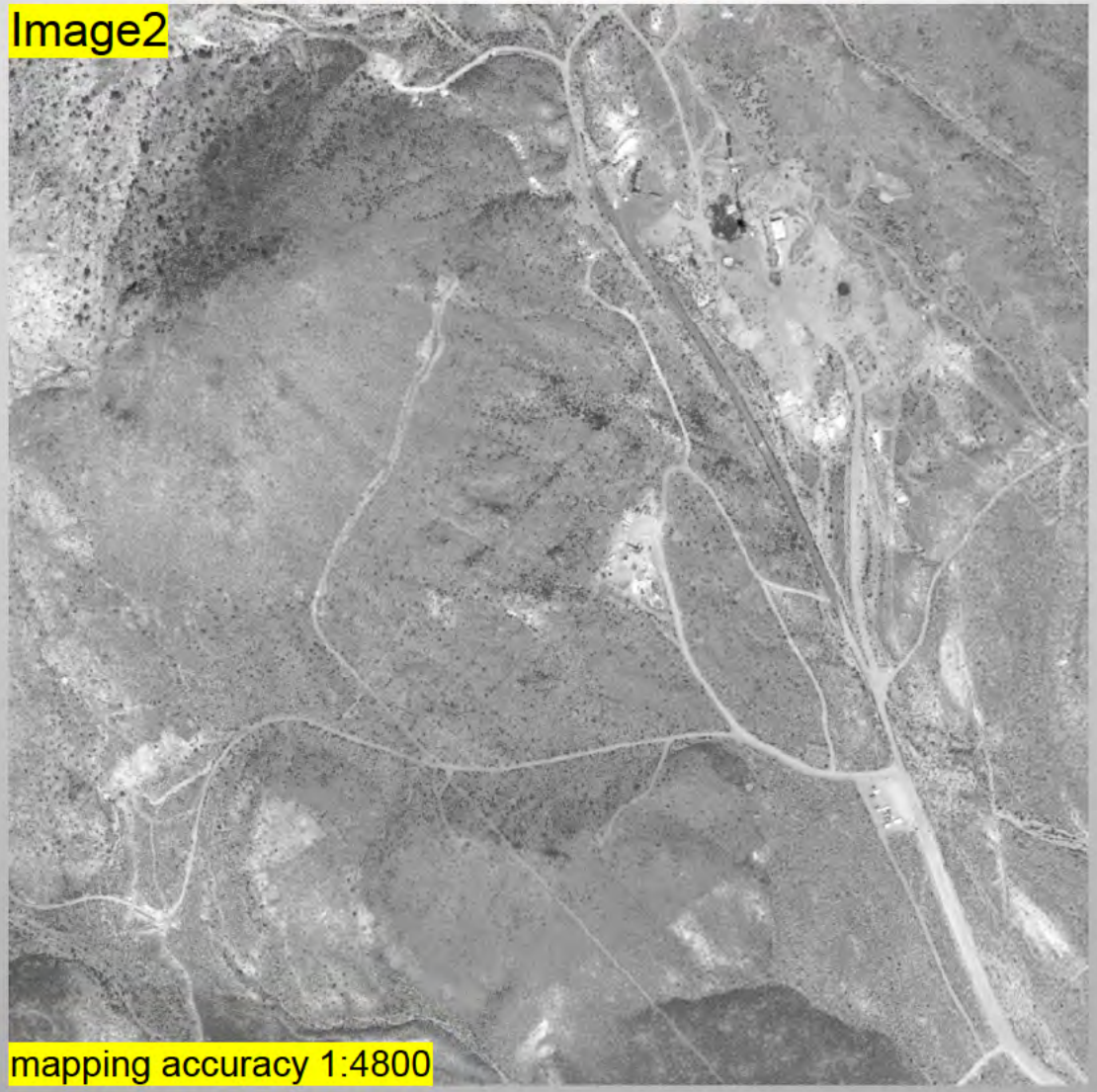


*original warp image should be histogram equalized and normalized [0,1]

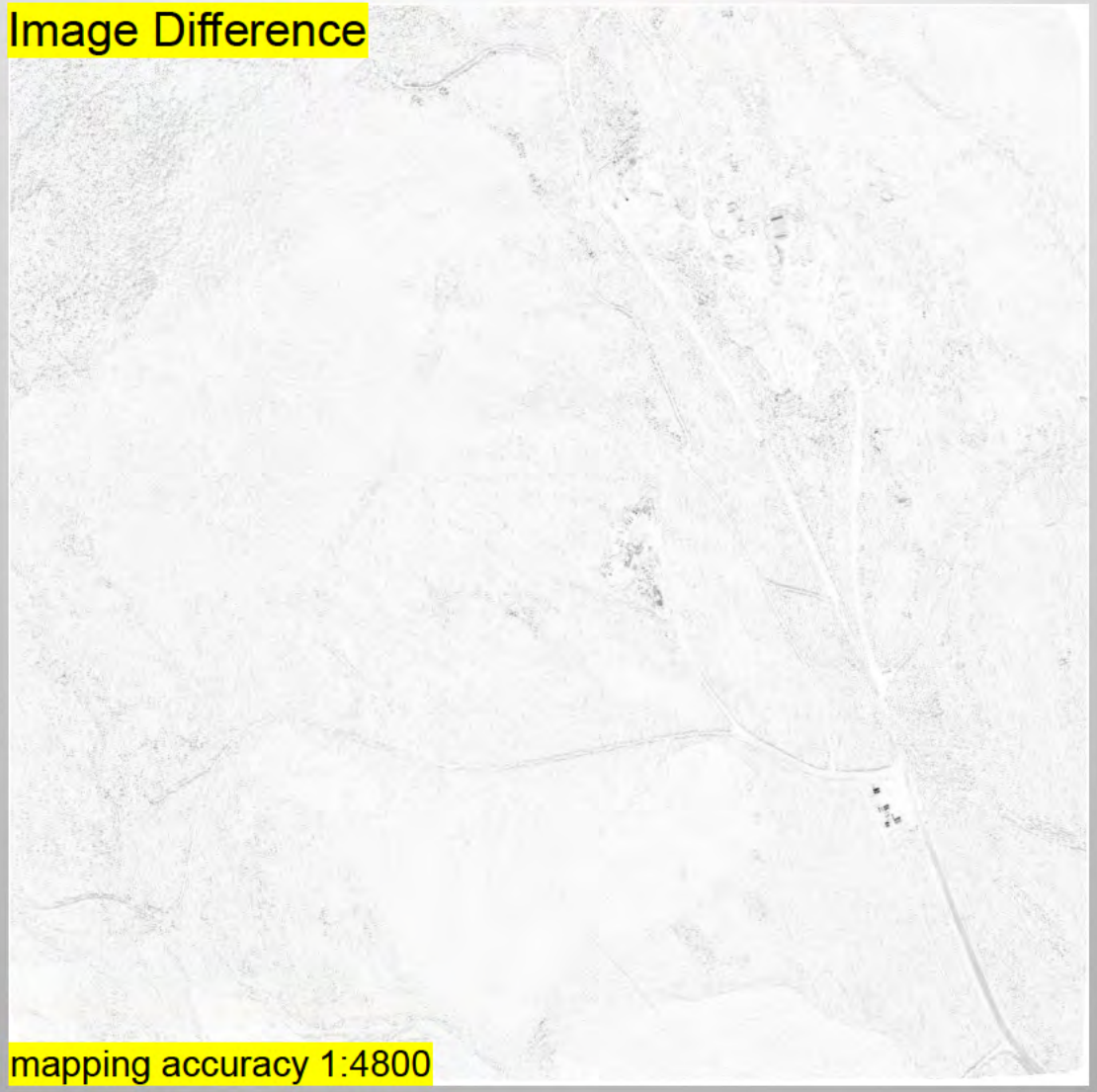
Results: Nevada National Security Site



Results: Nevada National Security Site



Results: Nevada National Security Site

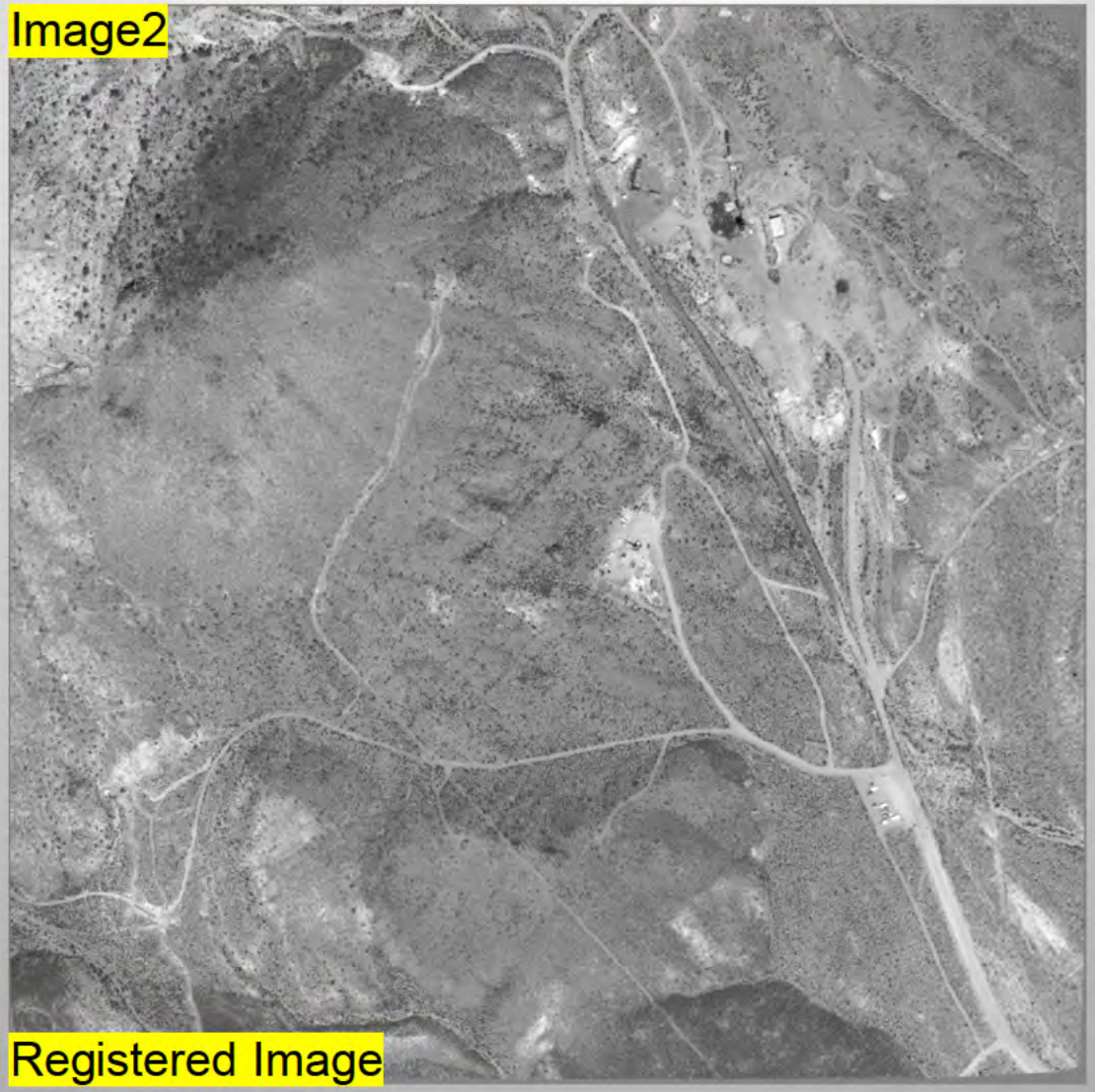


More Change

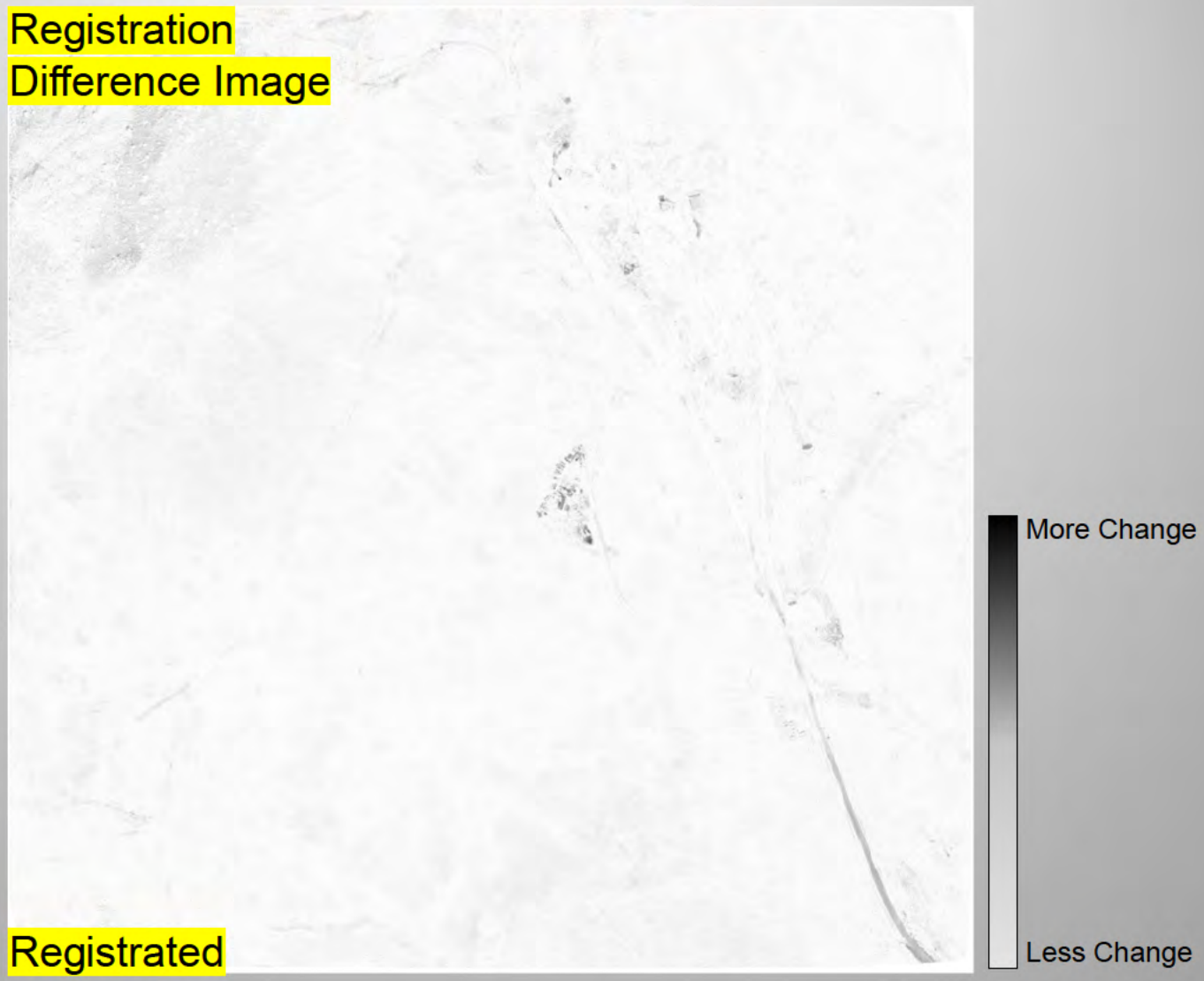
Less Change

Results: Nevada National Security Site

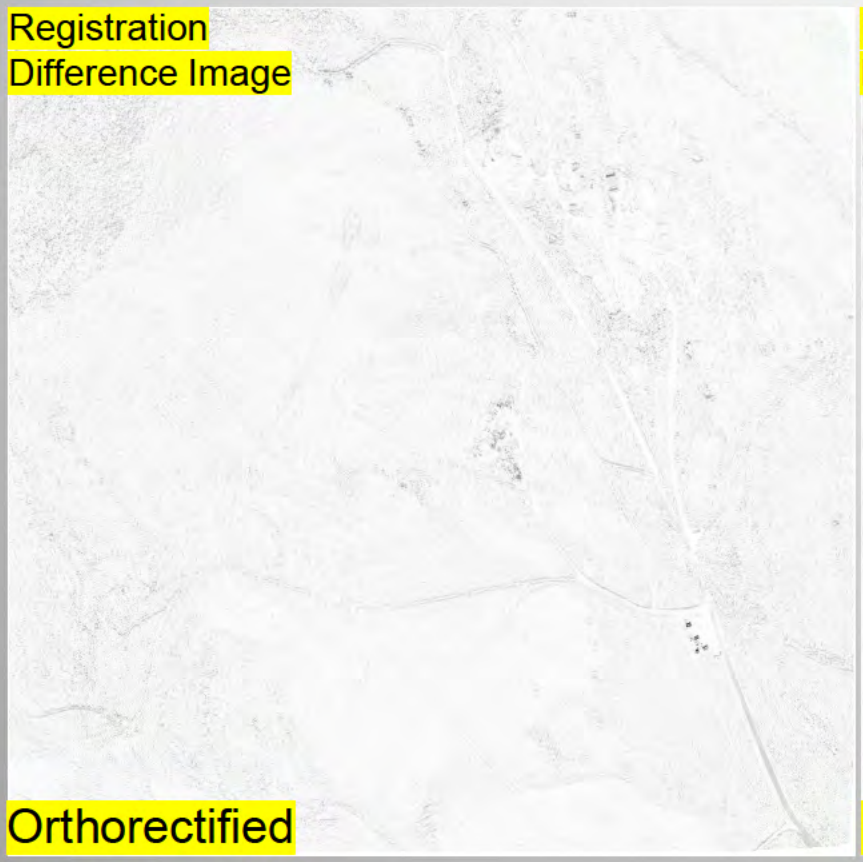
Results: Nevada National Security Site



Results: Nevada National Security Site



Results: Nevada National Security Site

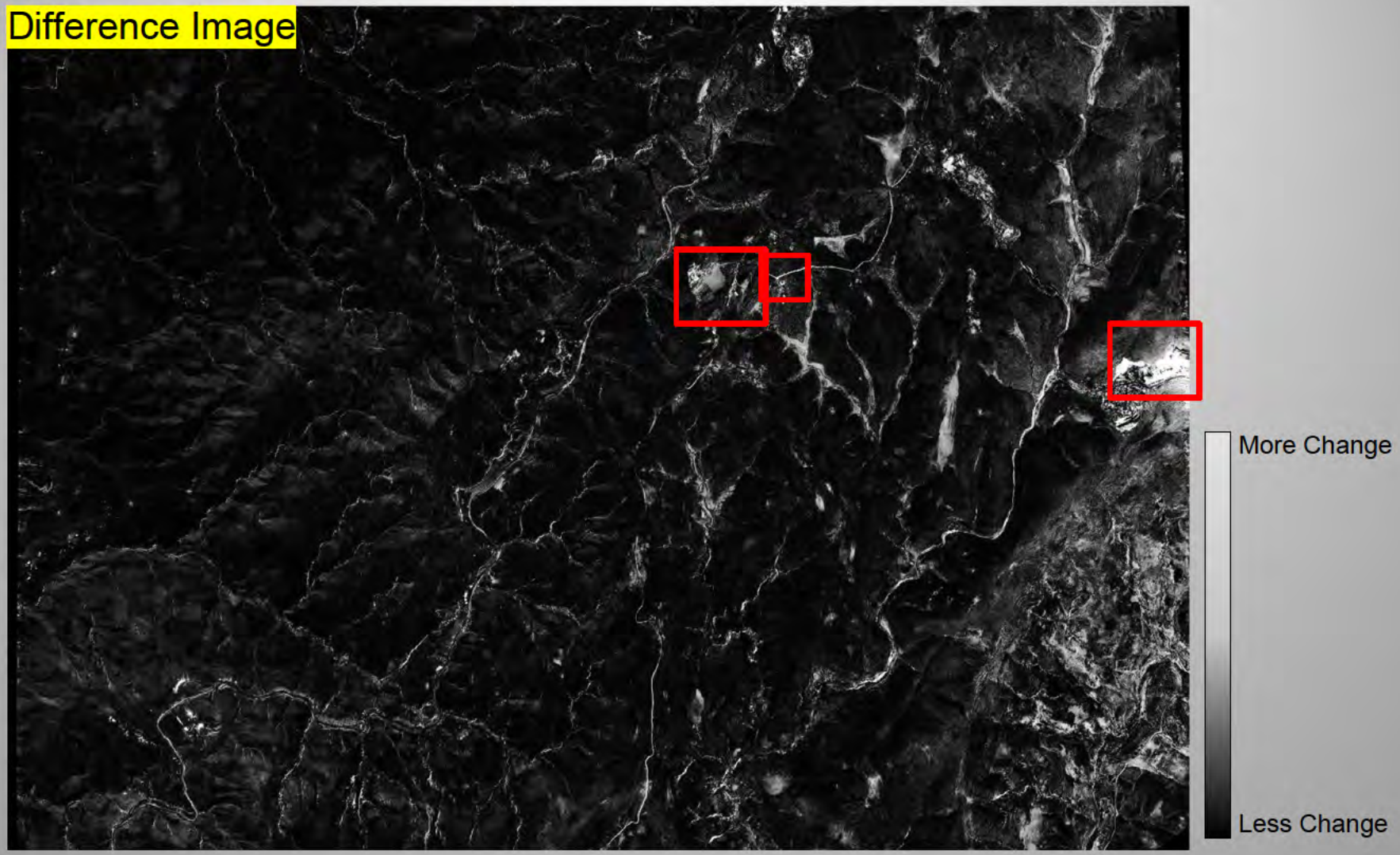


Results: Jordan Site

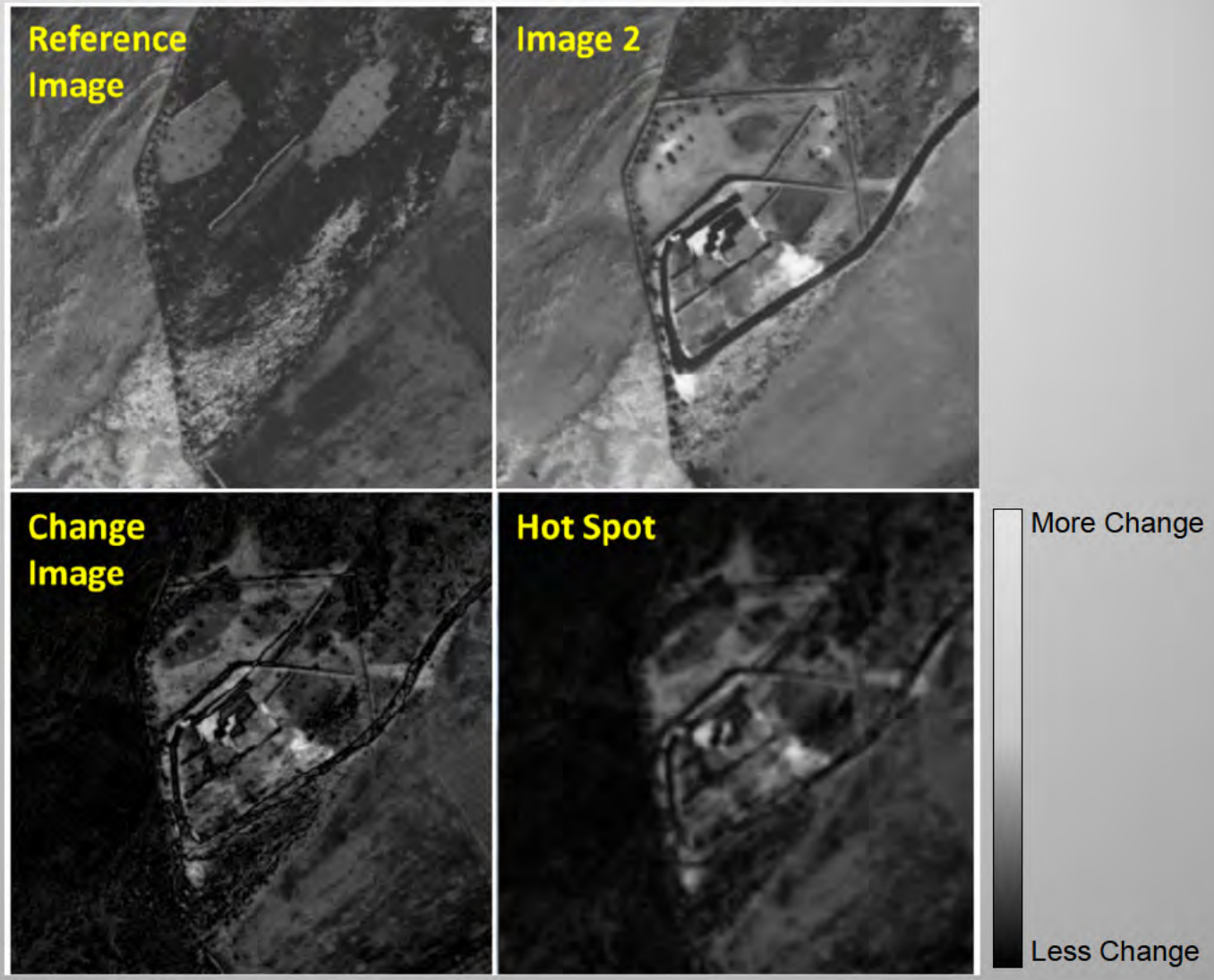
Results: Jordan Site

Results: Jordan Site

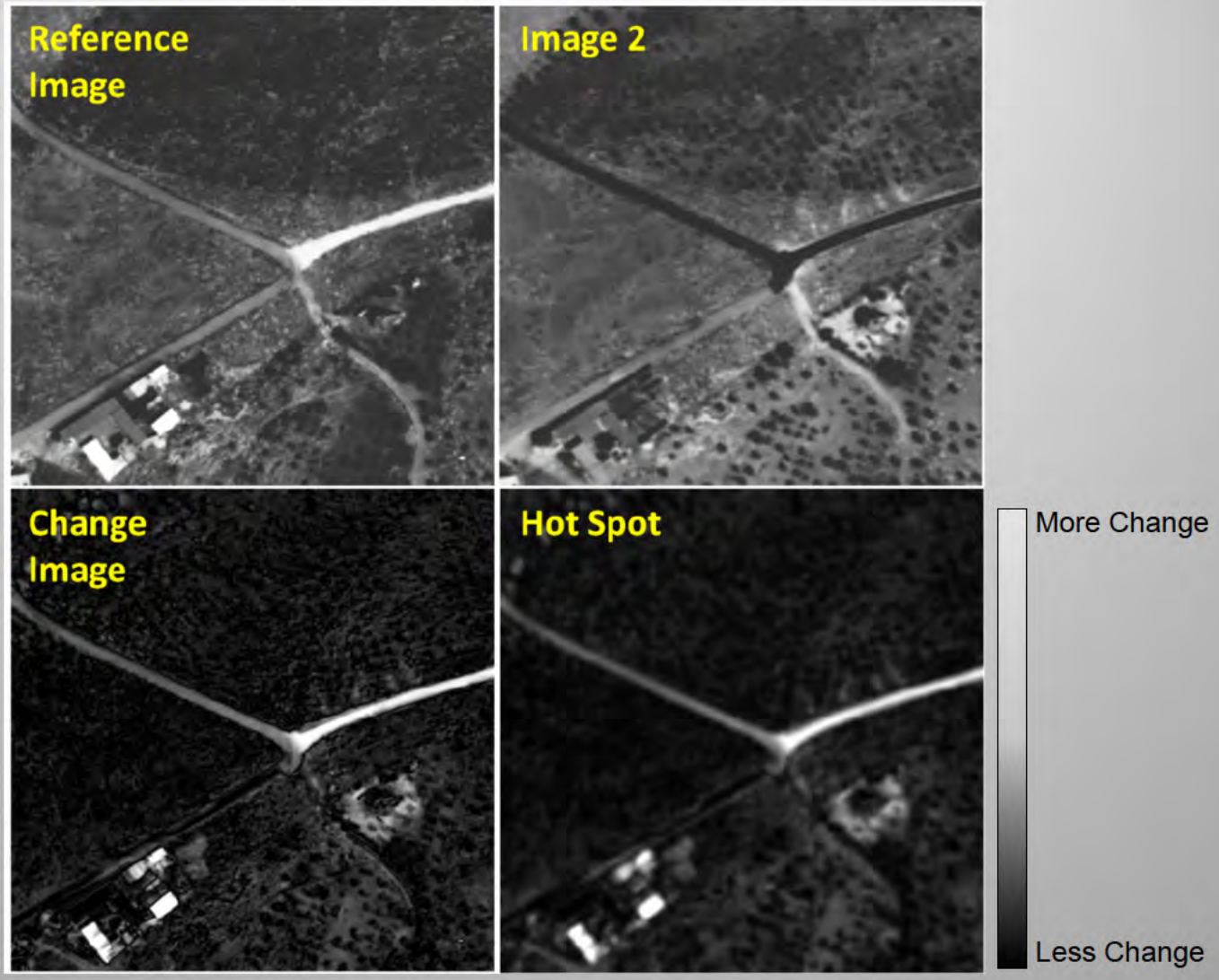
Results: Jordan Site



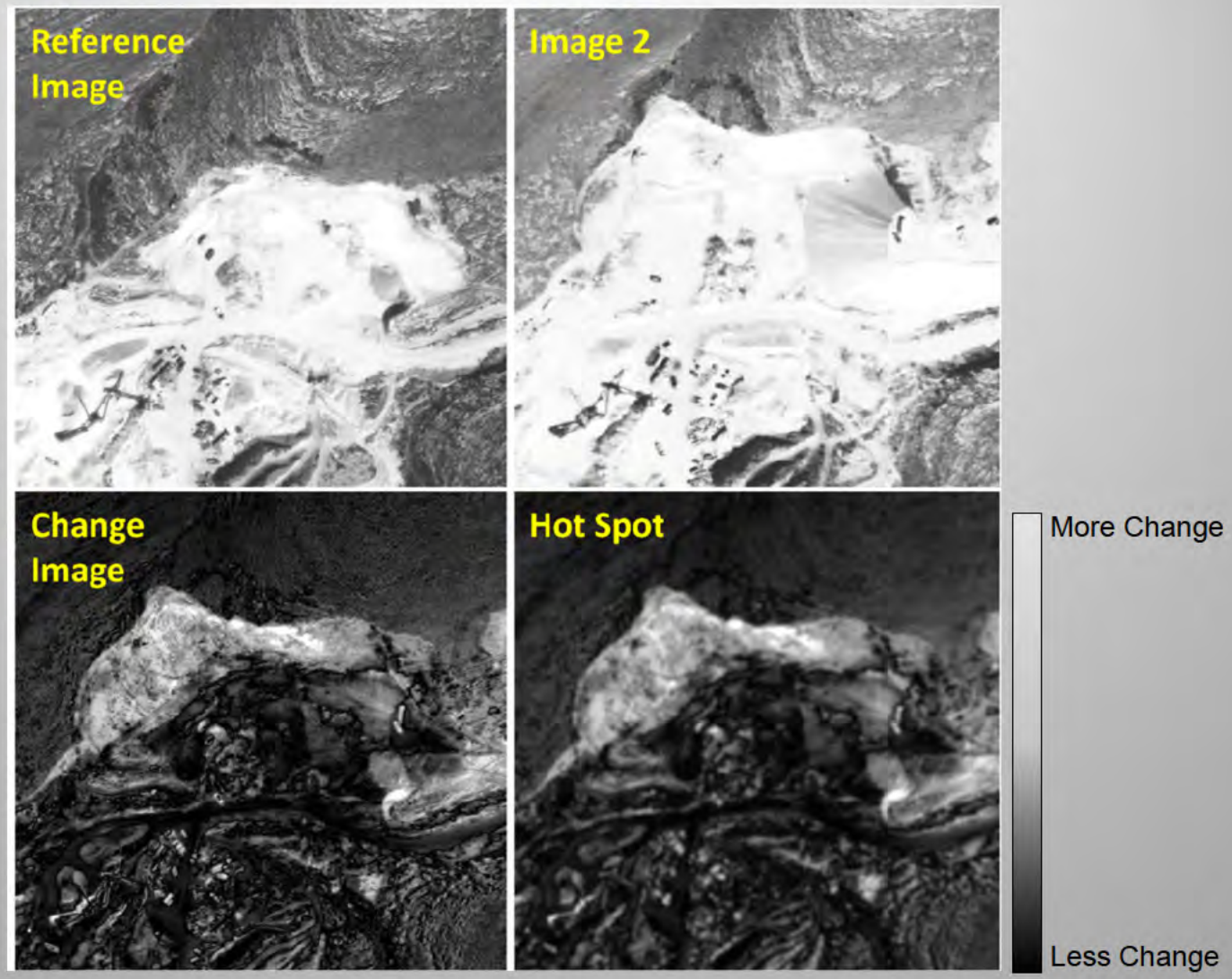
Results: Jordan Site



Results: Jordan Site



Results: Jordan Site



Conclusions

- Pixel-level change detection requires sub-pixel alignment
- Image registration can be used on orthorectified or geo-registered images to improve alignment to sub-pixel levels
- Registered image difference show reduced background clutter variability and increased true positive change scores

Acknowledgements

The Source Physics Experiments (SPE) would not have been possible without the support of many people from several organizations. The authors wish to express their gratitude to the National Nuclear Security Administration, Defense Nuclear Nonproliferation Research and Development (DNN R&D), and the SPE working group, a multi-institutional and interdisciplinary group of scientists and engineers.

Questions?

Backup Slides

NNSS Viewing Geometry

June 15, 2011
minInTrackViewAngle = -0.9;
maxInTrackViewAngle = -0.7;
meanInTrackViewAngle = -0.8;
minCrossTrackViewAngle = 12.5;
maxCrossTrackViewAngle = 12.6;
meanCrossTrackViewAngle = 12.6;
minOffNadirViewAngle = 12.6;
maxOffNadirViewAngle = 12.6;
meanOffNadirViewAngle = 12.6;

Sept. 2, 2014
minInTrackViewAngle = -4.8;
maxInTrackViewAngle = -4.6;
meanInTrackViewAngle = -4.7;
minCrossTrackViewAngle = 6.8;
maxCrossTrackViewAngle = 6.9;
meanCrossTrackViewAngle = 6.9;
minOffNadirViewAngle = 8.3;
maxOffNadirViewAngle = 8.3;
meanOffNadirViewAngle = 8.3;

Δview angle =
= np.sqrt((-.8 - -4.7)**2 + (12.6 - 6.9)**2)
= 6.90º

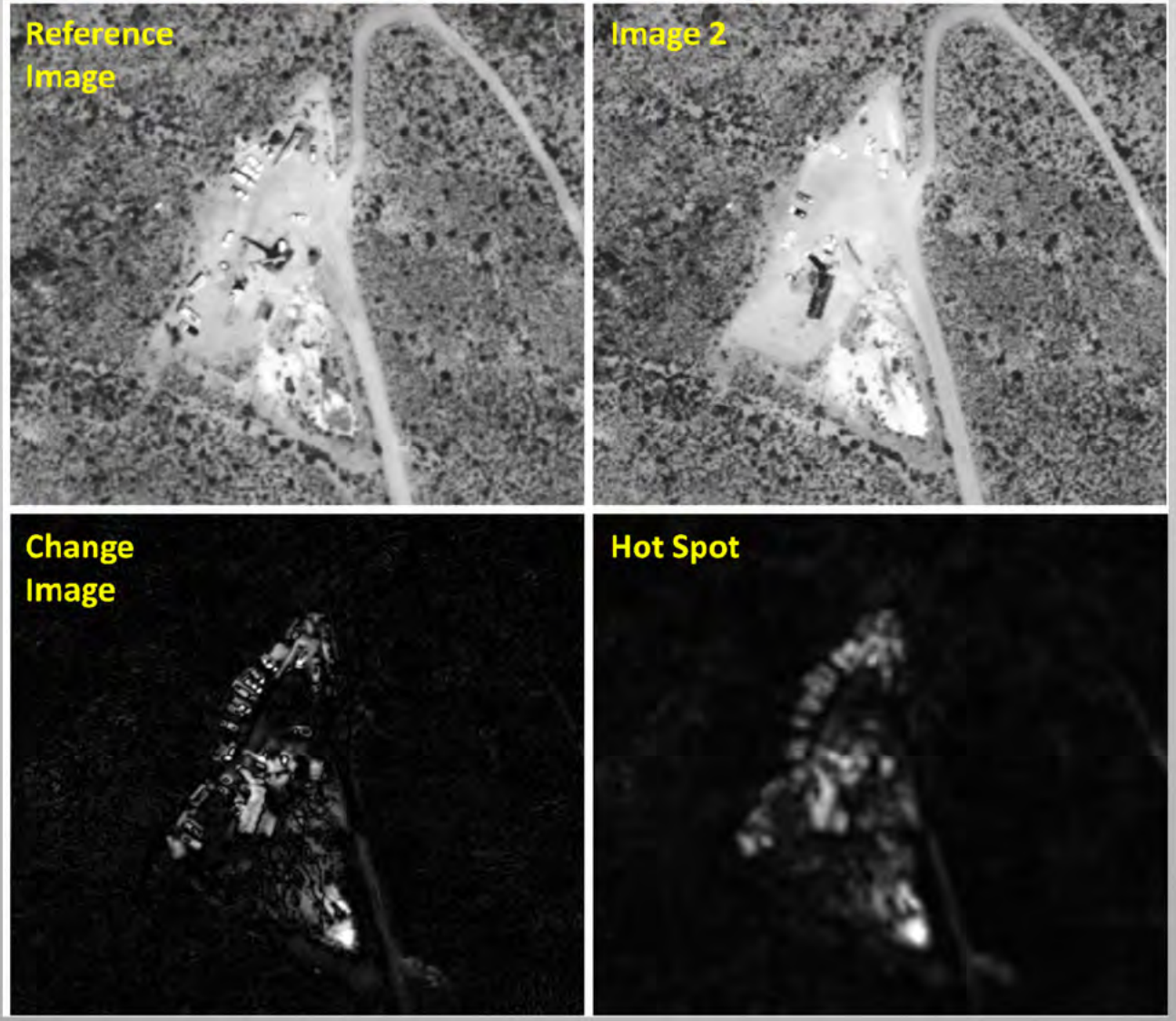
Jordan Site Viewing Geometry

Feb 23, 2011
minInTrackViewAngle = 11.9;
maxInTrackViewAngle = 12.0;
meanInTrackViewAngle = 12.0;
minCrossTrackViewAngle = 5.0;
maxCrossTrackViewAngle = 5.1;
meanCrossTrackViewAngle = 5.0;
minOffNadirViewAngle = 12.9;
maxOffNadirViewAngle = 13.0;
meanOffNadirViewAngle = 13.0;

Sept. 27, 2014
minInTrackViewAngle = 0.5;
maxInTrackViewAngle = 0.7;
meanInTrackViewAngle = 0.6;
minCrossTrackViewAngle = -34.3;
maxCrossTrackViewAngle = -34.3;
meanCrossTrackViewAngle = -34.3;
minOffNadirViewAngle = 34.3;
maxOffNadirViewAngle = 34.4;
meanOffNadirViewAngle = 34.3;

Δview angle =
= np.sqrt((12 - .6)**2 + (5 + 34.3)**2)
= 40.9º

Results: Nevada National Security Site



More Change

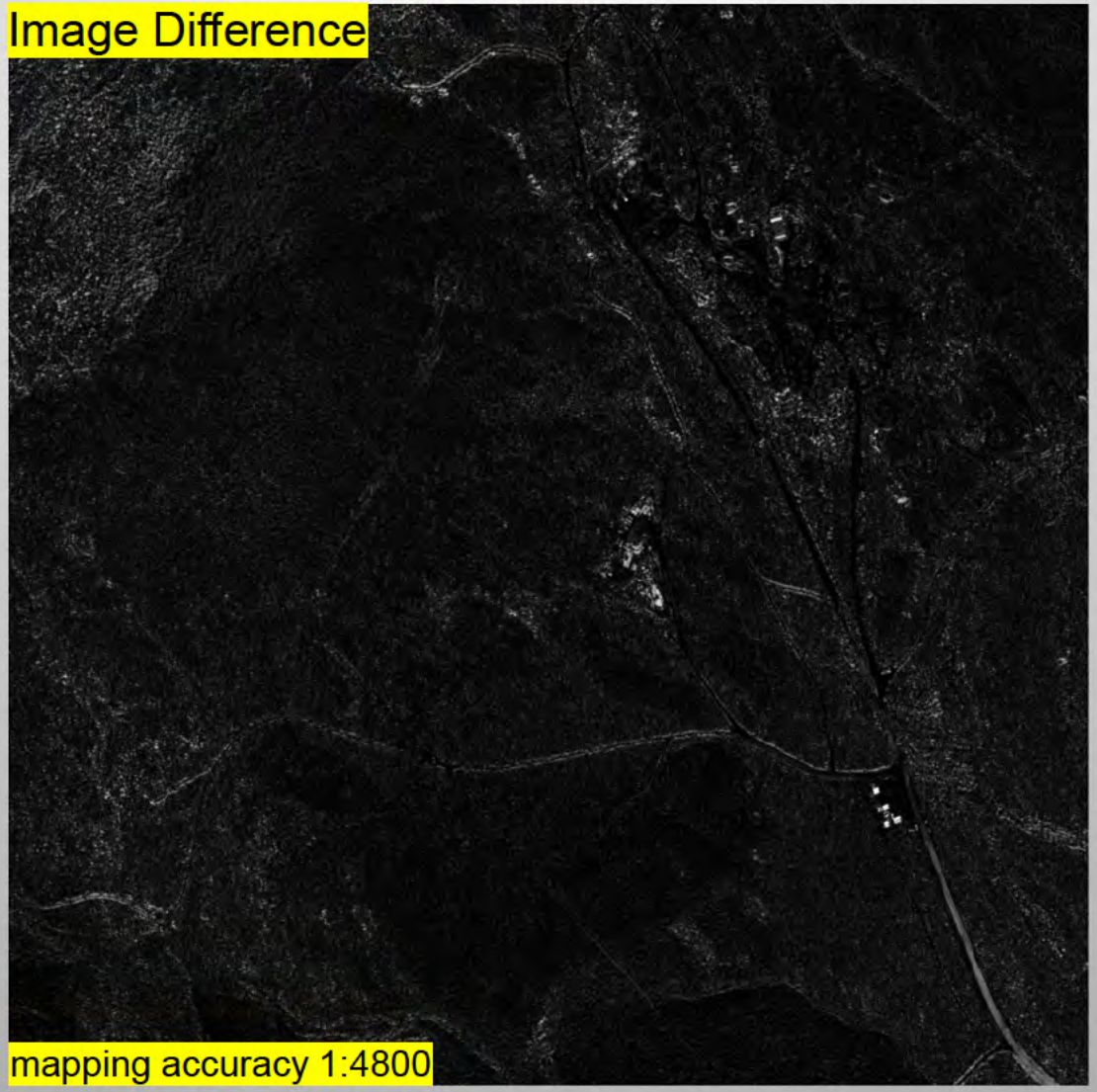
Less Change

Image Demons Result

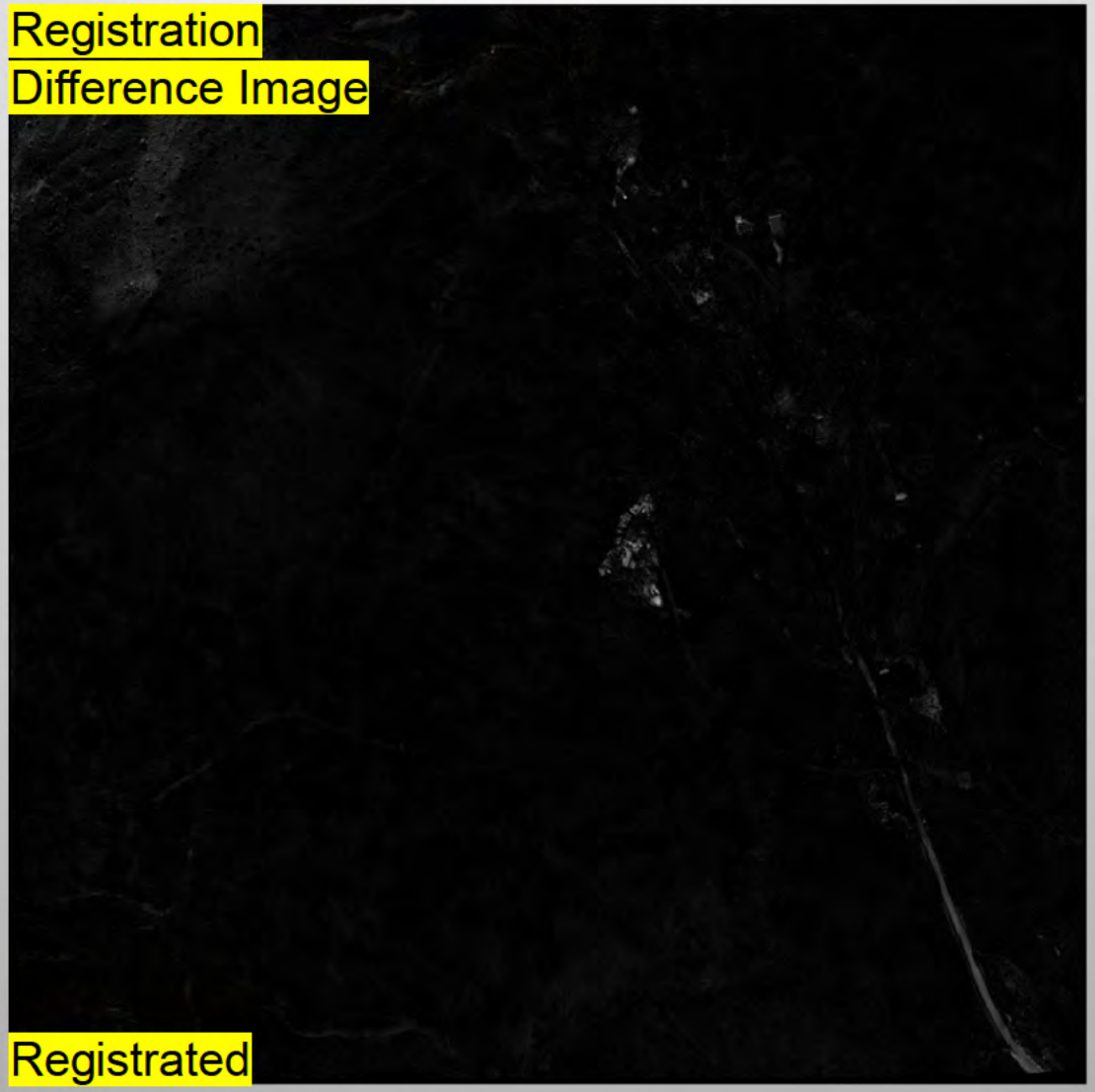
Original Image

Image demons Warped Image

Nevada National Security Site

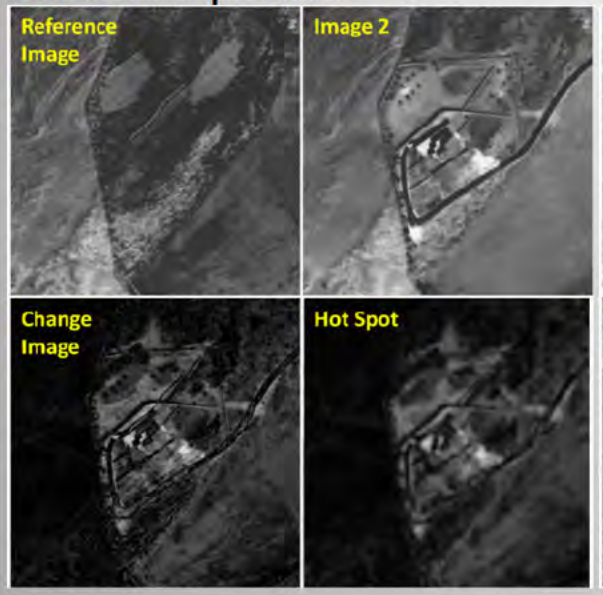


Nevada National Security Site

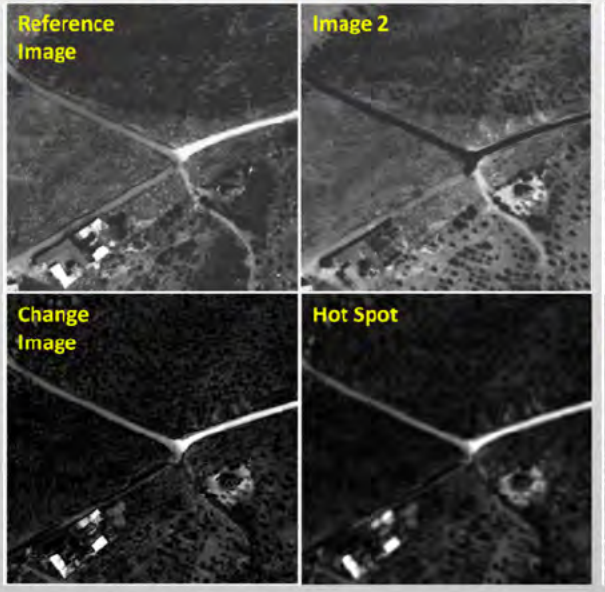


Results: Jordan Site

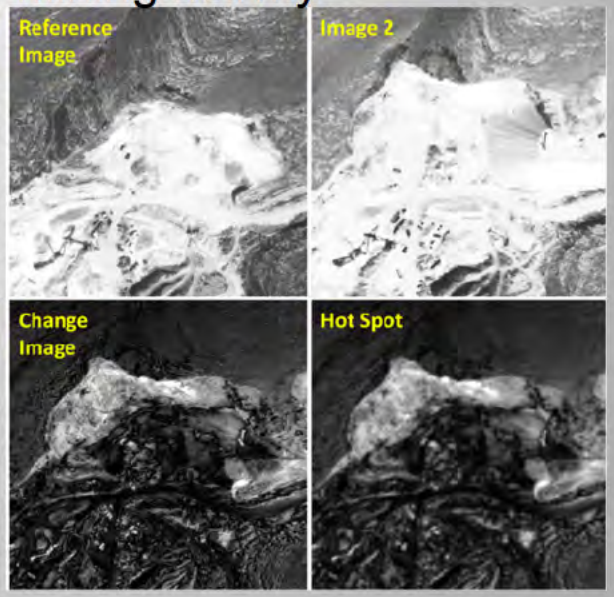
New compound



New road + roof



Mining activity



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