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CENTER FOR UNMANNED AIRCRAFT SYSTEMS

Infrastructure Monitoring

John Hedengren, Ryan Farrell and Kevin Franke
Brigham Young University

Project Overview

- Objective - To achieve sub-cm point cloud accuracy using optical sensing methods
- Duration - 2 years
- Budget - $80,000
- Deliverables for current year
  - Study methods for improving computer vision models vs. LiDAR
  - Measure impact of model error in engineering applications

Outline

- Infrastructure Case Studies
  - Steinaker Dam
  - Chile Earthquake
  - North Salt Lake Landslide
- Improving Model Quality
  - Image Collection Optimization
  - New Processing Techniques
    - Proposed Study

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INFRASTRUCTURE CASE STUDIES

Infrastructure Case Studies

Study	Objective
Steinaker Dam, Vernal UT	Measure and observe slope failure
Iquique Chile Earthquake	Develop and compare metrics to those taken by hand
North Salt Lake Landslide, UT	Detect change and movement

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Steinaker Dam- USBR

- In October 2014, we assisted with the investigation of a slope failure at Steinaker Dam in Vernal, Utah
- Due to airspace restrictions, photos were taken from a manned helicopter
- Camera equipped with GPS tracker
- Analysis is ongoing; working models (point cloud, mesh, and texture), DEM, and orthophoto developed so far

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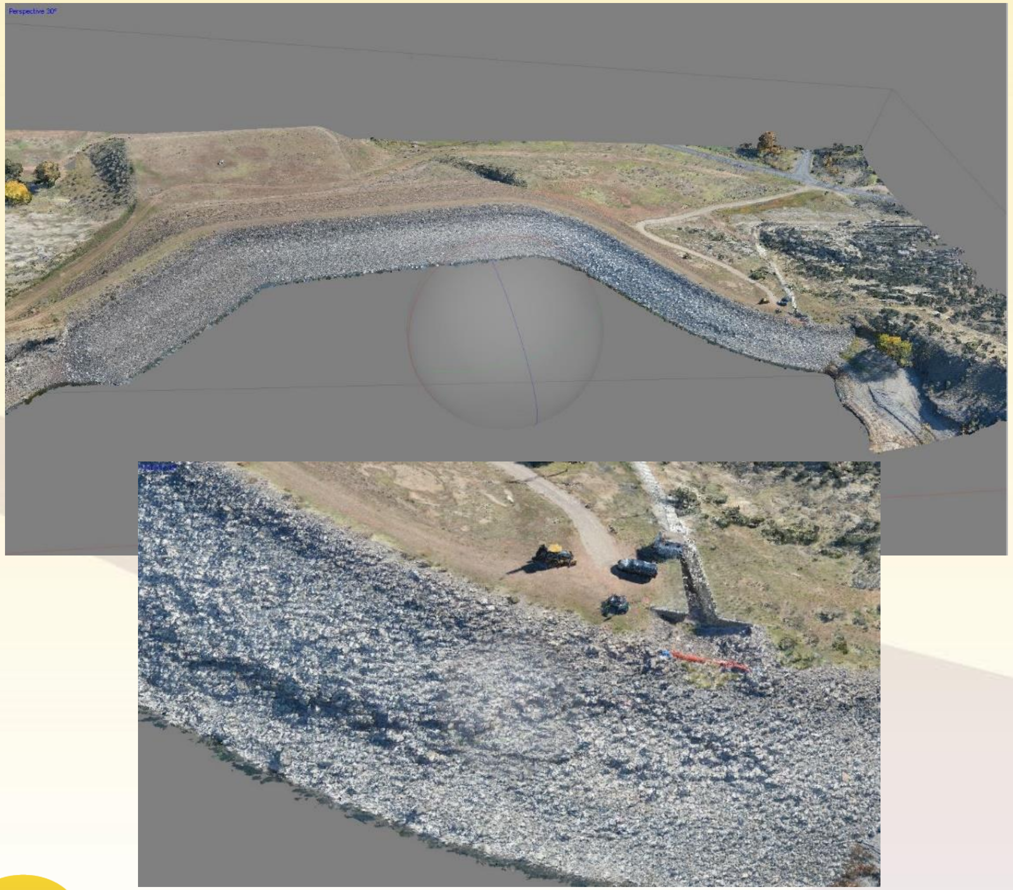
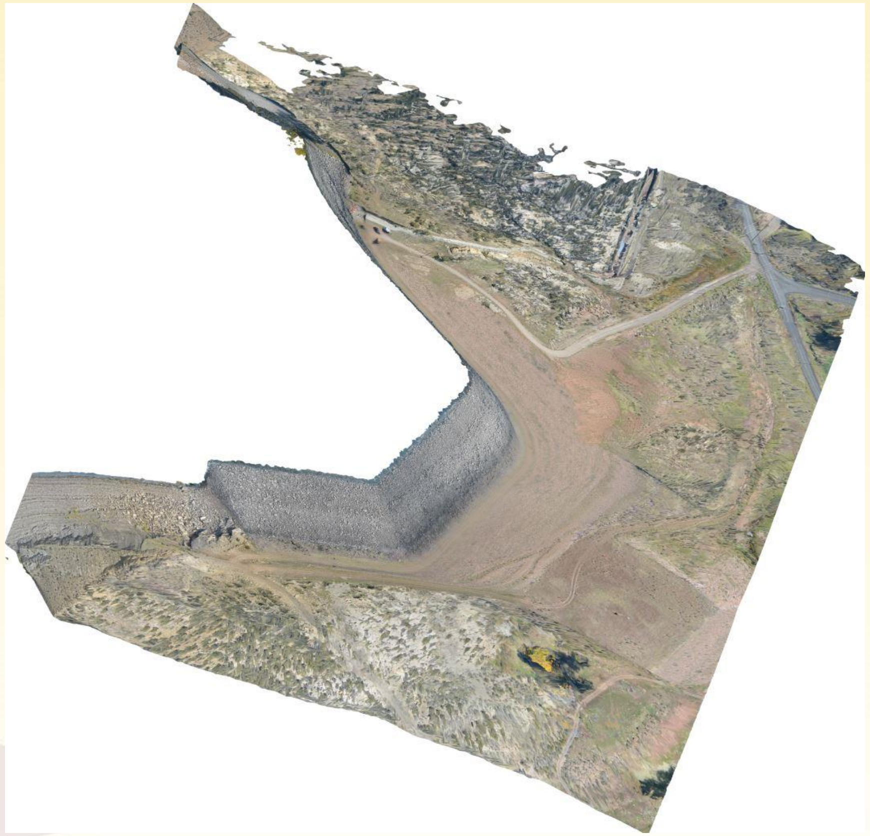
Steinaker Dam- USBR

Point Cloud Models



Orthophoto



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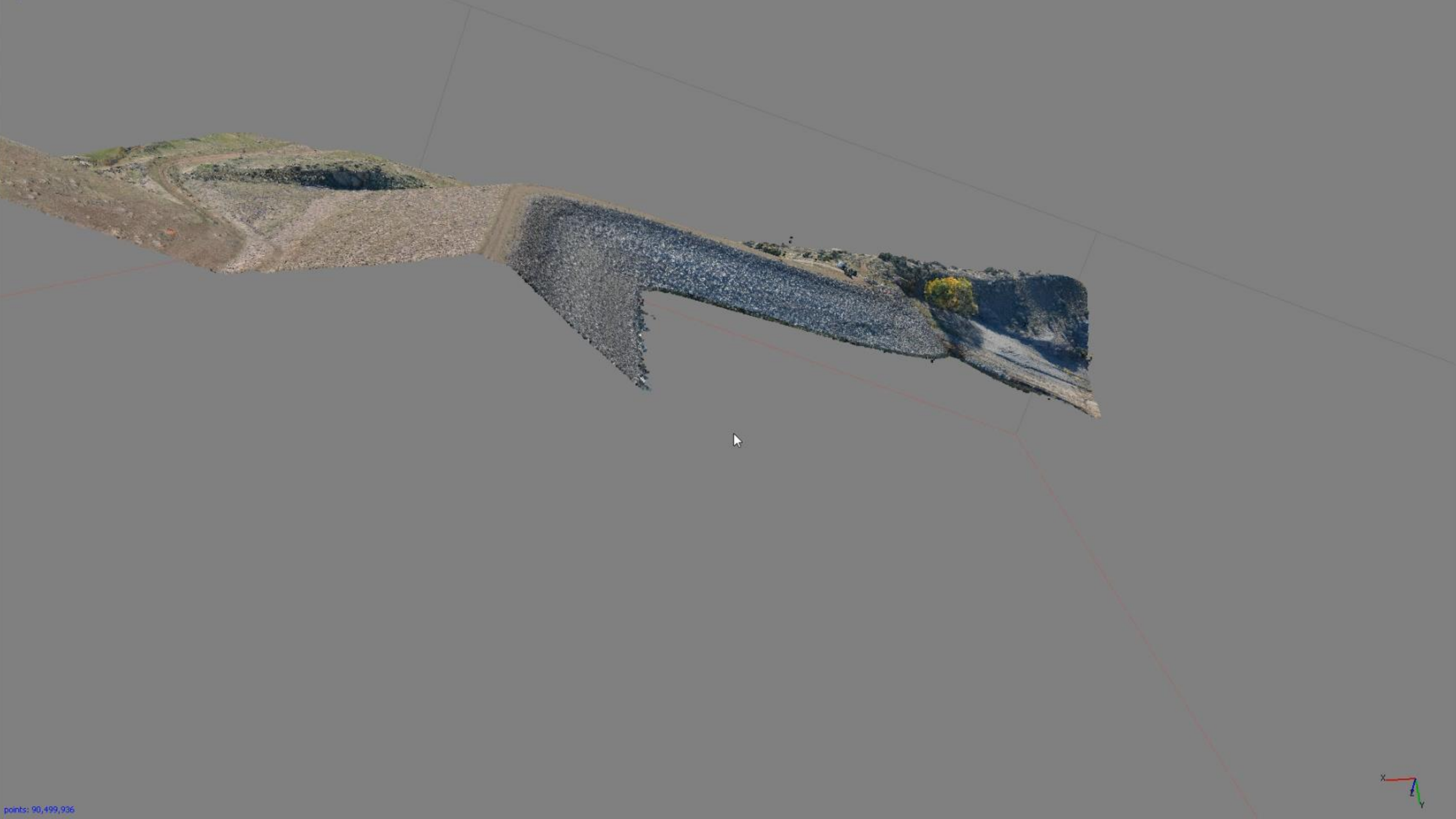
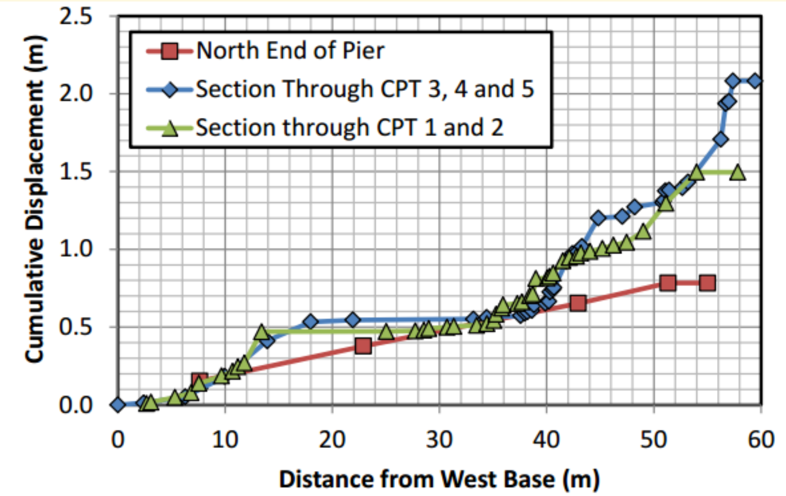


points: 90,499,936
X
Y

Iquique Chile Earthquake

- On April 1st 2014, Iquique, Chile experienced a M8.2 earthquake; BYU collaborated on the geotechnical report
- Imagery gathered with a quadcopter platform was used to develop 3D models of affected infrastructure
- Intention is to develop metrics comparable to those taken on-site, proving the viability of UAV-based remote sensing for post-earthquake reconnaissance



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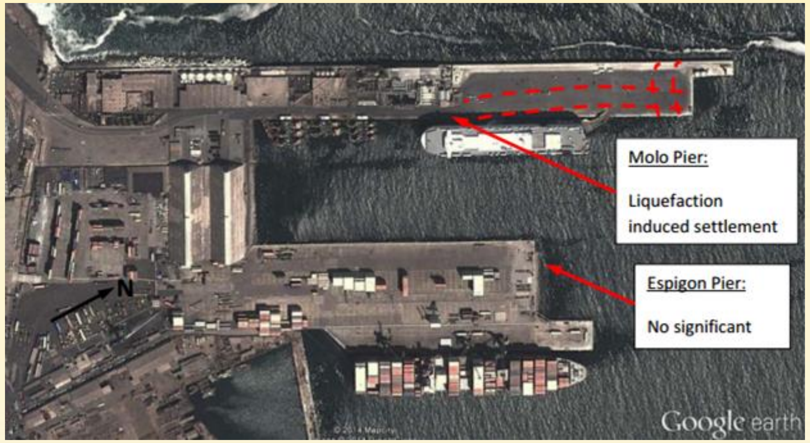
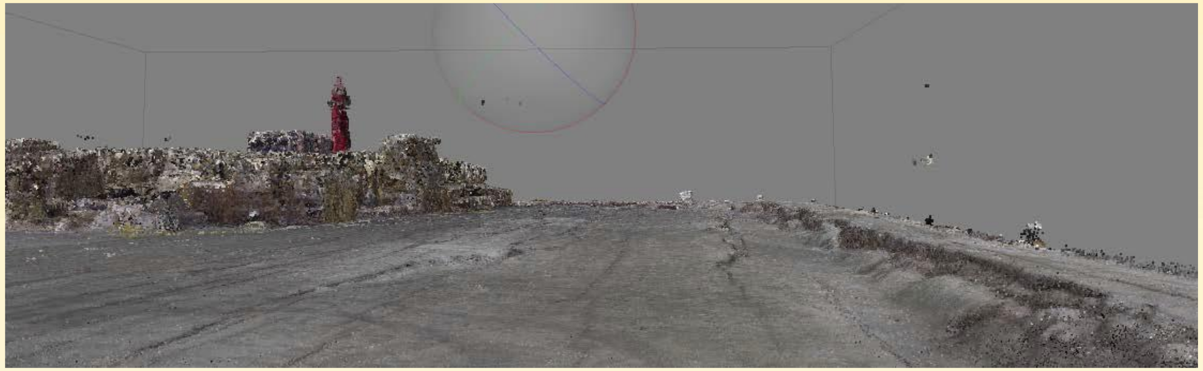
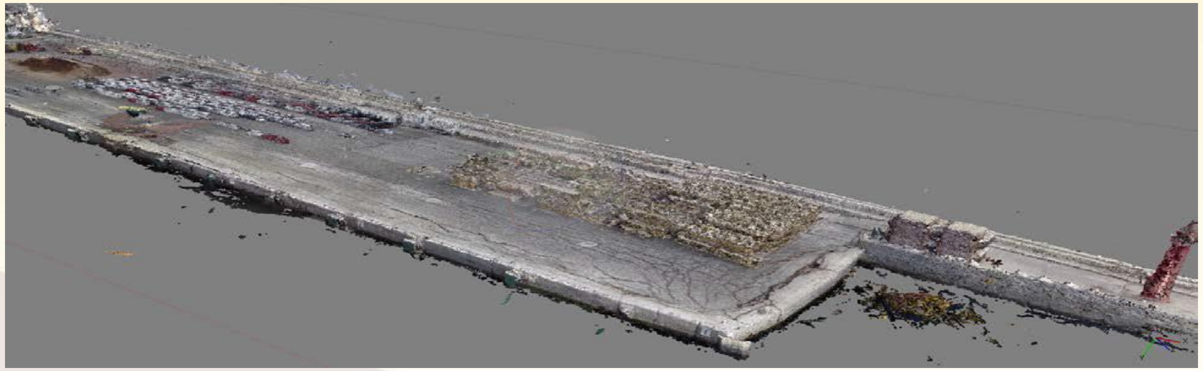
Iquique Chile Earthquake







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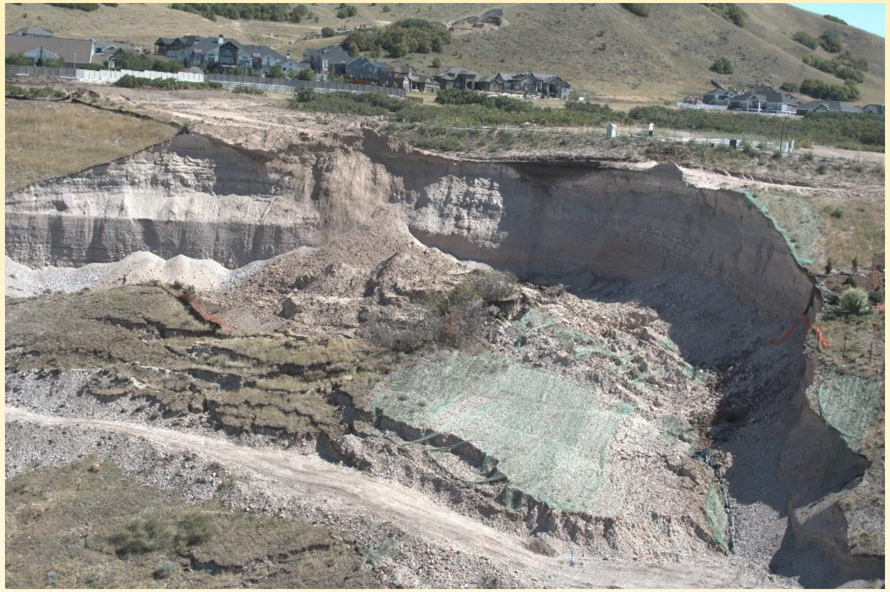
North Salt Lake Landslide

- On August 5th 2014, a landslide occurred in North Salt Lake, Utah. The slide destroyed one home and put several others in danger
- UGS and FEMA requested that we fly the site. We flew an sUAV over the slide on August 6th, 14th and 28th
- The goal of these flights was to gauge drift over the month following the initial slide
- The comparison between the models is ongoing
- Collaboration with the city of North Salt Lake and UGS is ongoing as well



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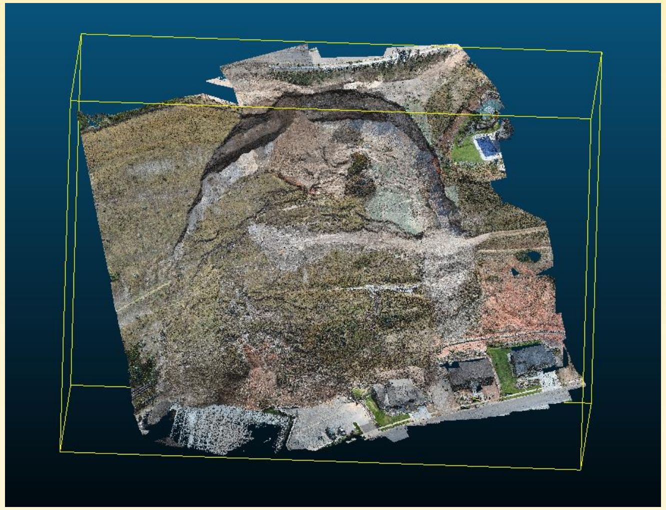
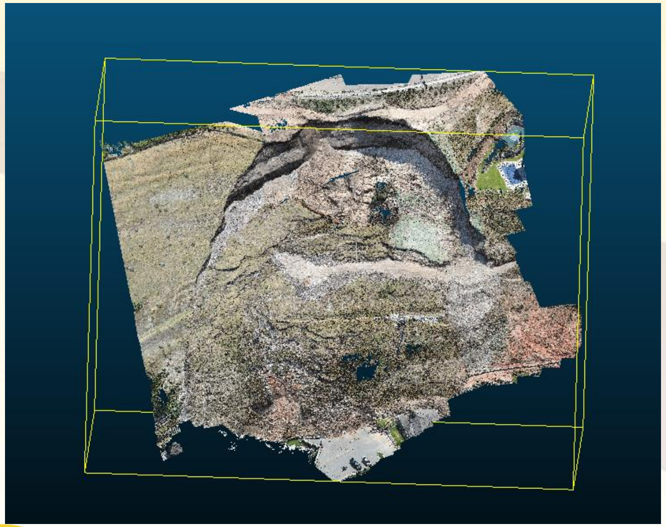
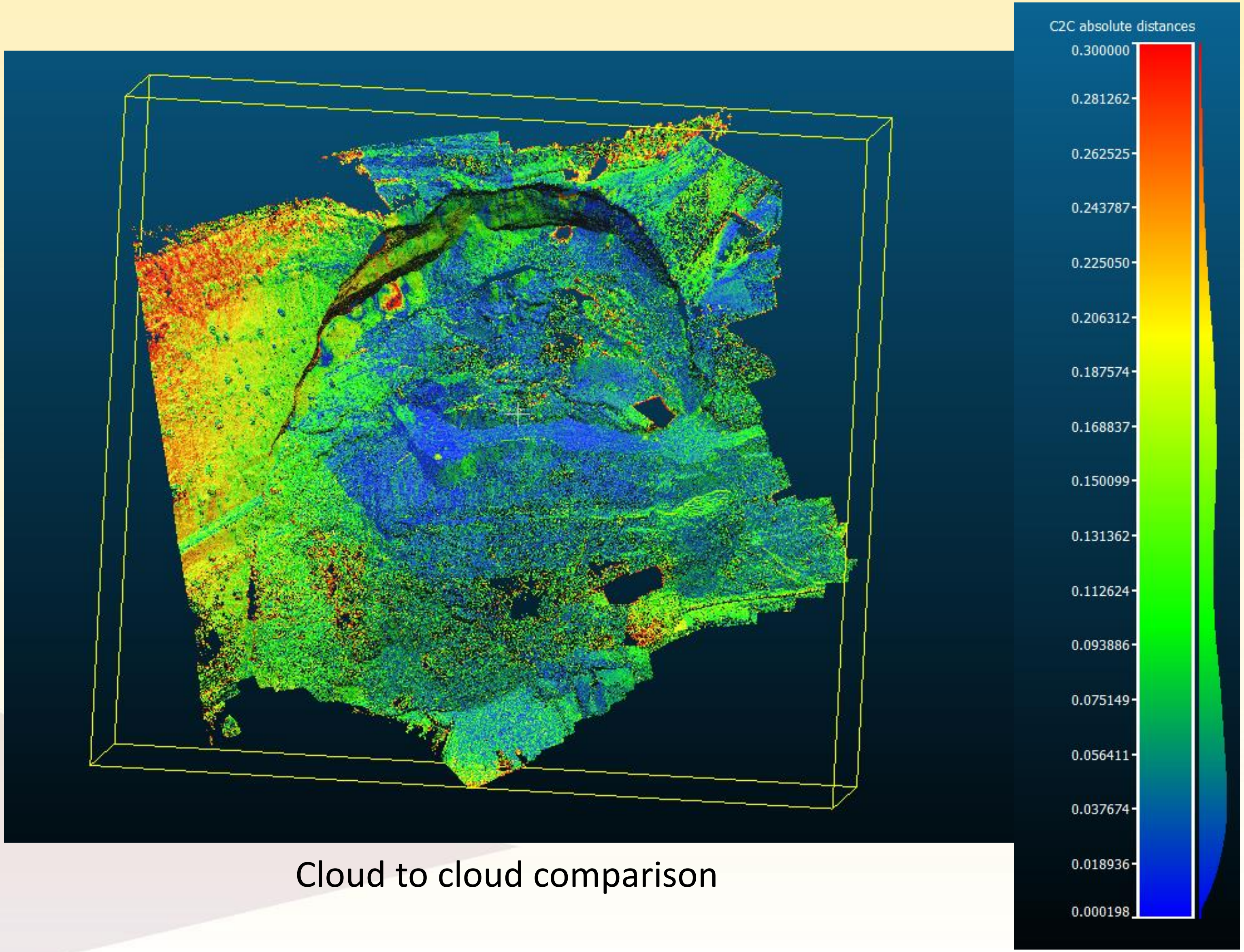
Landslide Comparison Models

August 14th



August 28th





Cloud to cloud comparison

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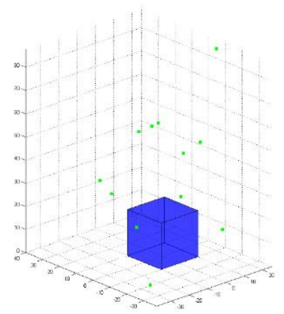
IMPROVING MODEL QUALITY

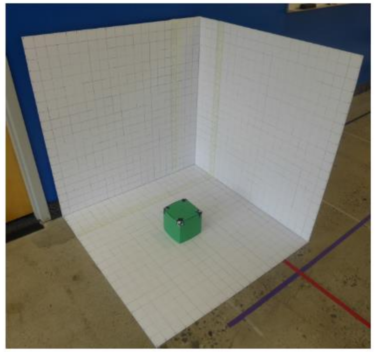
Image Collection Optimization

Image Collection Optimization

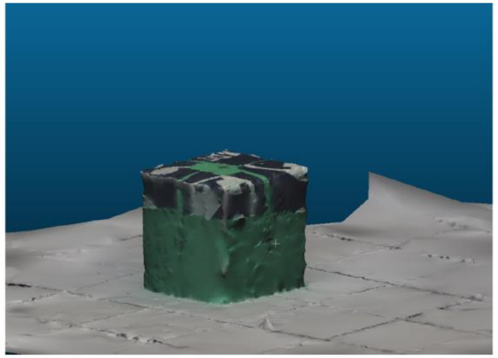
Lab Scale Camera Testing



(a) Simulation bounding box



(b) Coordinate system



c) Lateral view of the box in the 3D model

Table 2: 95% Confidence Interval Quality Assessment Results

Camera (Pictures)	5 (cm)	10 (cm)	15 (cm)	20 (cm)
Nikon (24)	5.0085 – 5.1432	9.8117 –10.0742	15.0002– 15.2123	19.6559–19.8679
Nikon (18)	5.0539 – 5.1441	9.6818 –10.0458	14.4786– 14.6990	19.6635–19.8602
LumiX (18)	4.6382 – 5.0428	–	–	–
GoPro (24)	4.4230 – 4.7730	–	–	–

Image Collection Optimization

Flight Path Optimization Workflow

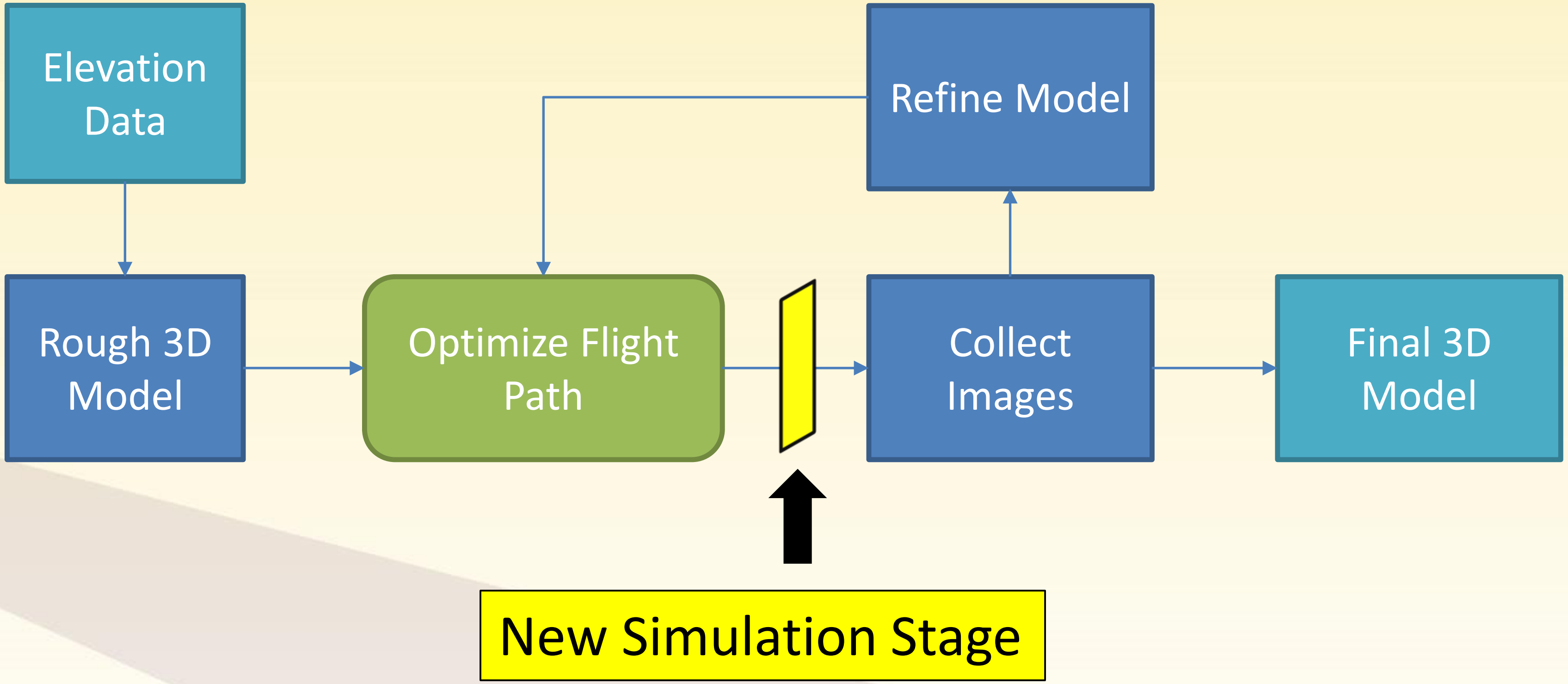


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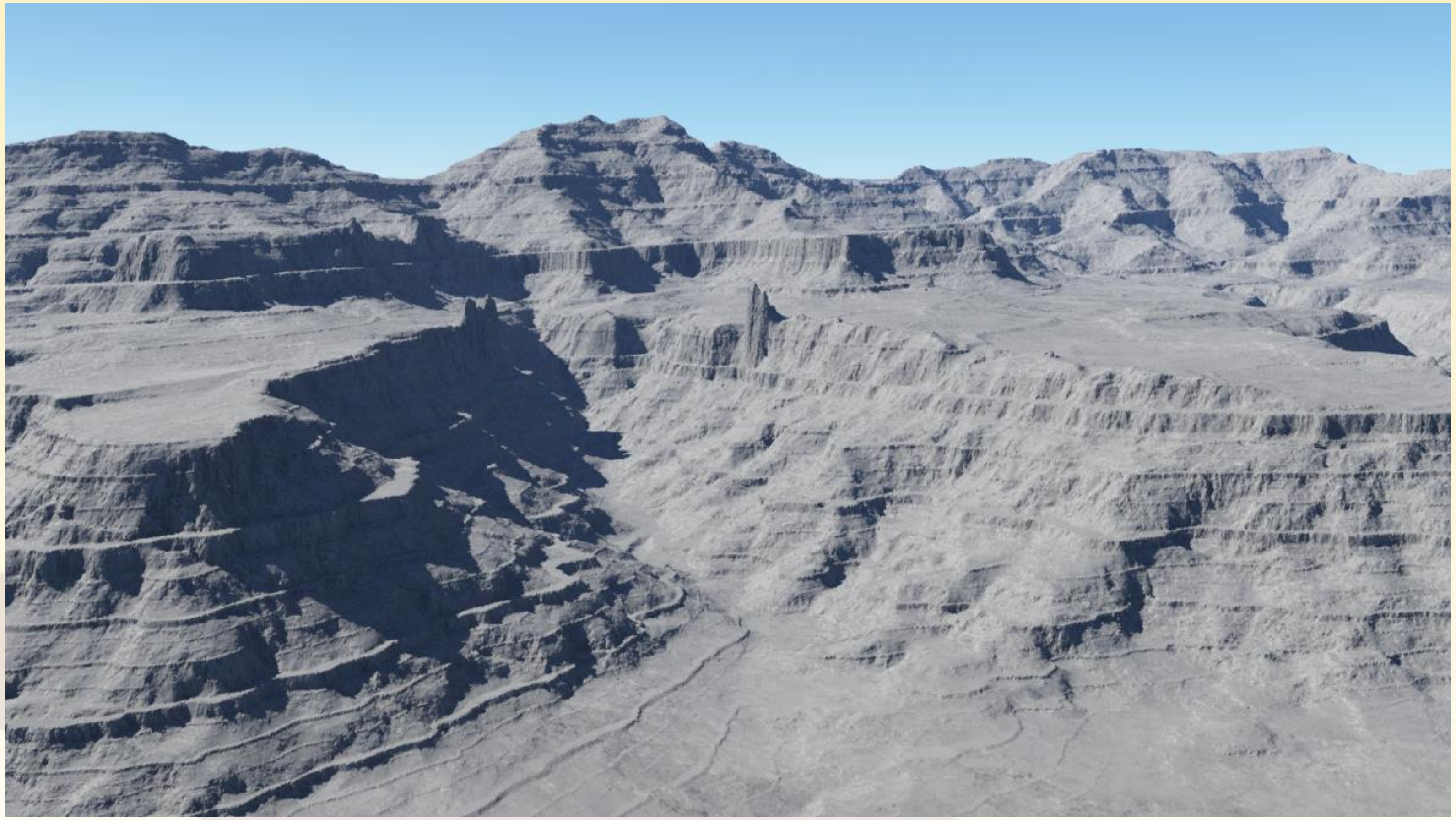
Image Collection Optimization

Terrain Simulation



Son of Blaze Canyon, Utah

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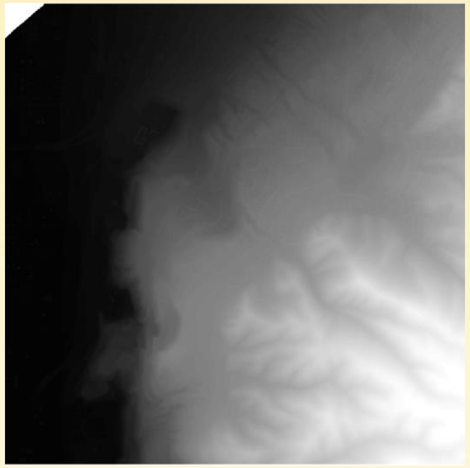
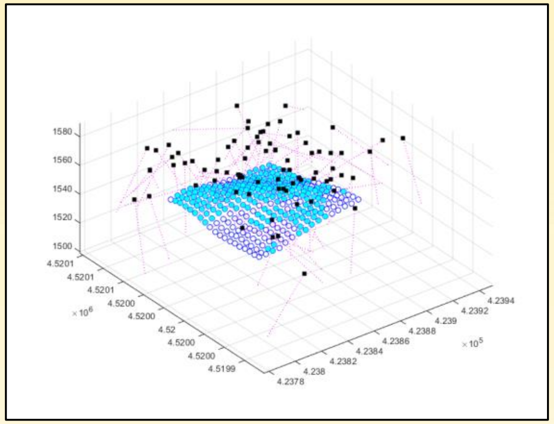
Image Collection Optimization

SIMULATION PIPELINE

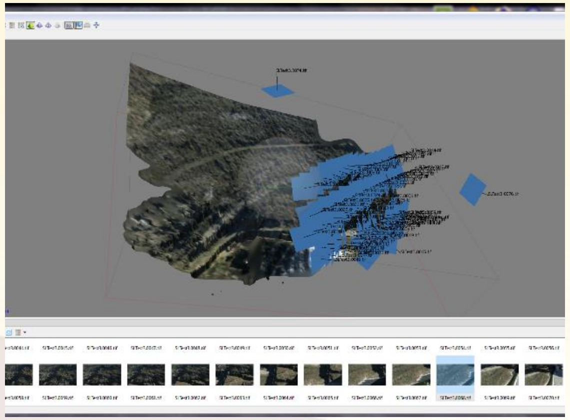


USGS Data

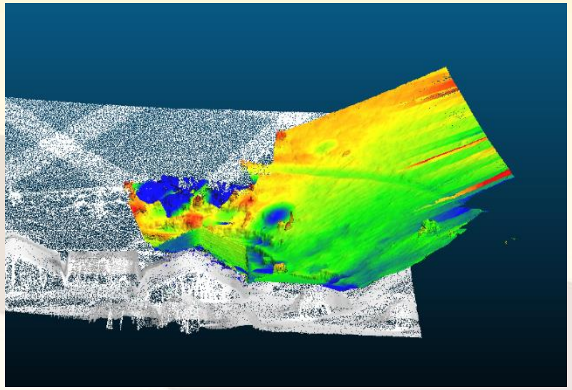


Flight Path Optimization

Terrain Simulator



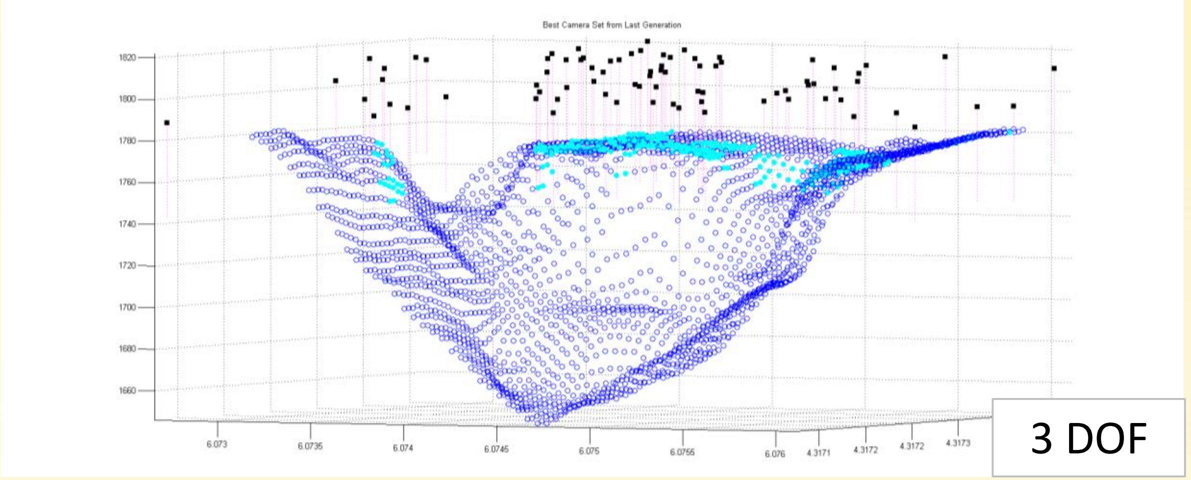
SfM Software



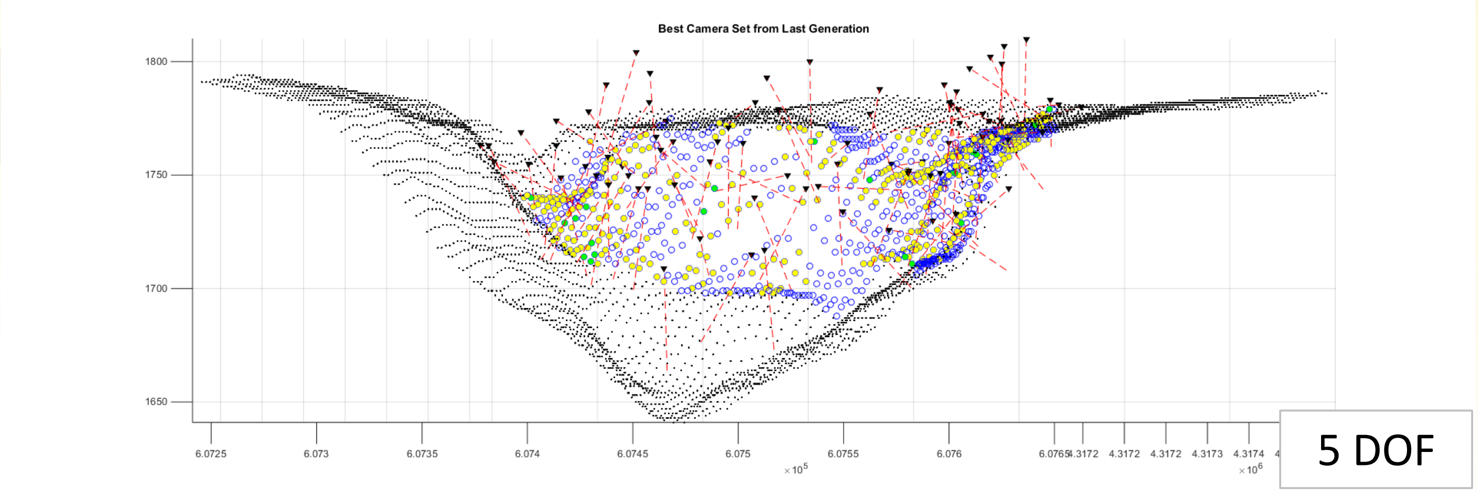
Point Cloud Comparison

Image Collection Optimization

5 Degree of Freedom Camera Optimization



3 Degrees of Freedom
- Latitude
- Longitude
- Elevation



5 Degrees of Freedom
- Latitude
- Longitude
- Elevation
- Camera Pitch
- Camera Yaw

Son of Blaze Canyon, Utah

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IMPROVING MODEL QUALITY

New Processing Techniques

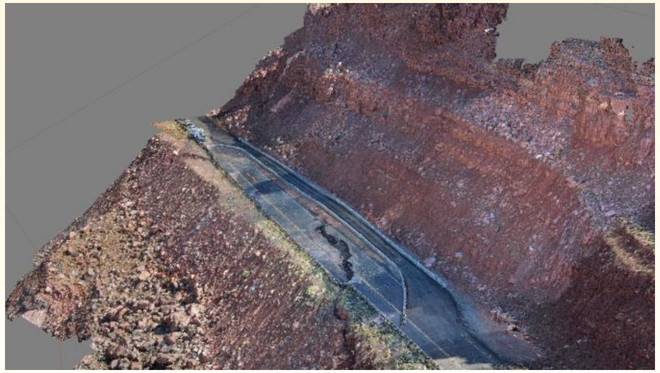
Improved Processing Workflow

- **Masking** – Crop out unwanted areas such as sky and water. Reduces processing time
- **Computer** - In-house assembled and upgraded processing computer. Large increase in processing capability
- **Processing Settings** - Ultra-High processing setting increased model density, however, processing time increased considerably

Before Masking

After Masking

Resulting Point Cloud



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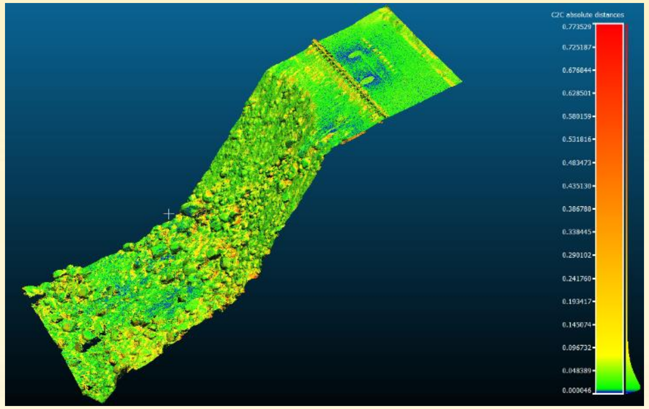
Results From Improved Processing Workflow

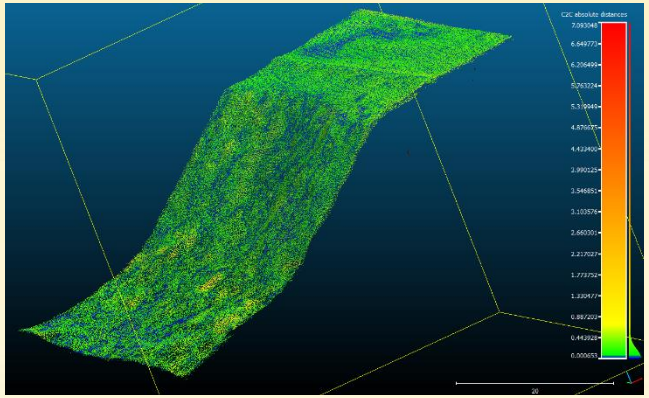
US-89 Arizona landslide

SkyJib and Nikon 7100 vs. LiDAR



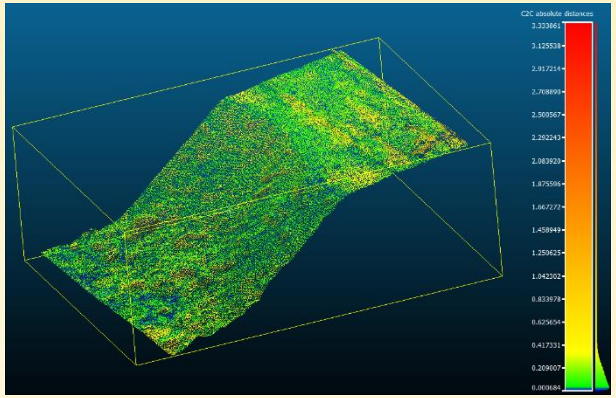
	Before	After
Resolution	6,919 pts/m^2	38,889 pts/m^2
Ground Nearest Distance	1.2 cm	.5 cm
Accuracy	3 cm	3 cm

Phantom and GoPro vs. LiDAR



	Before	After
Resolution	99 pts/m^2	2,061 pts/m^2
Ground Nearest Distance	10 cm	2.2 cm
Accuracy	14 cm	5 cm

Flying Wing and GoPro vs. LiDAR



	Before	After
Resolution	85 pts/m^2	797 pts/m^2
Ground Nearest Distance	10.8 cm	3.5 cm
Accuracy	14 cm	14 cm

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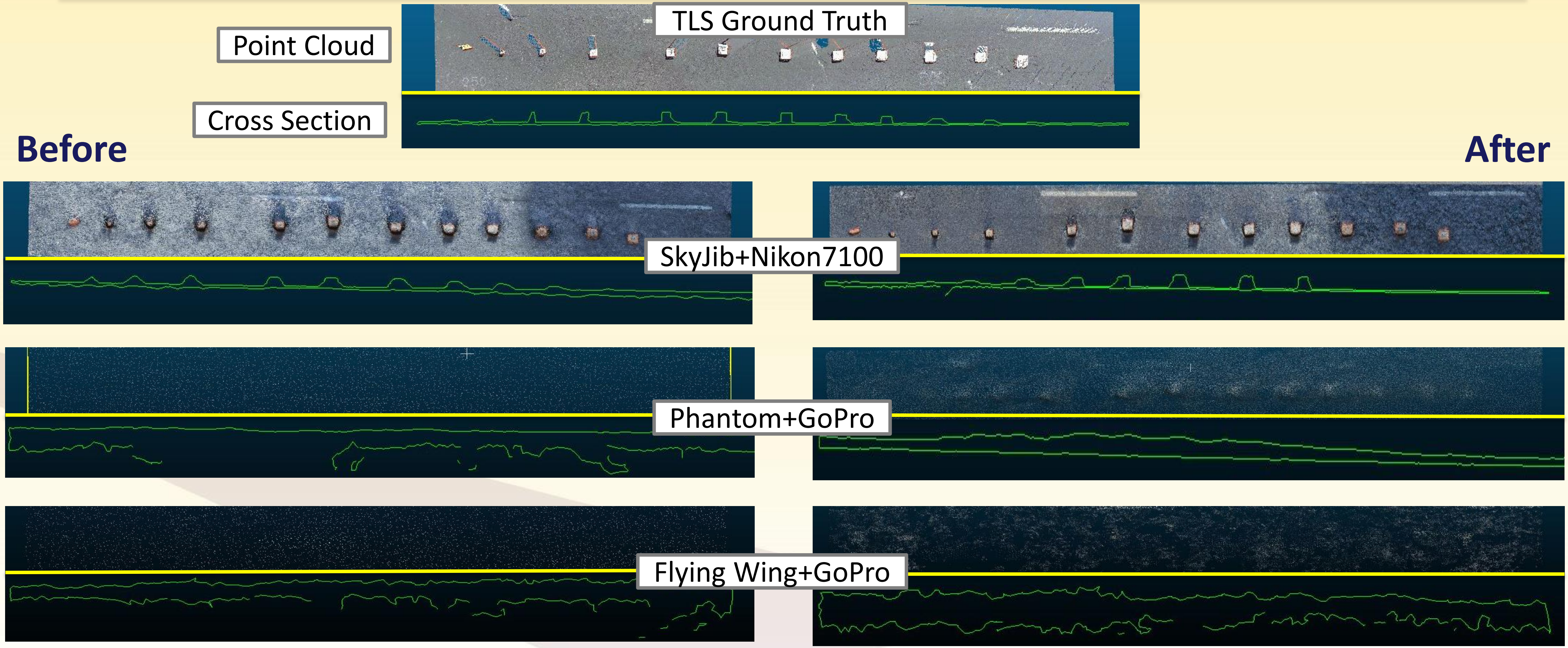
Comparison of Resolutions



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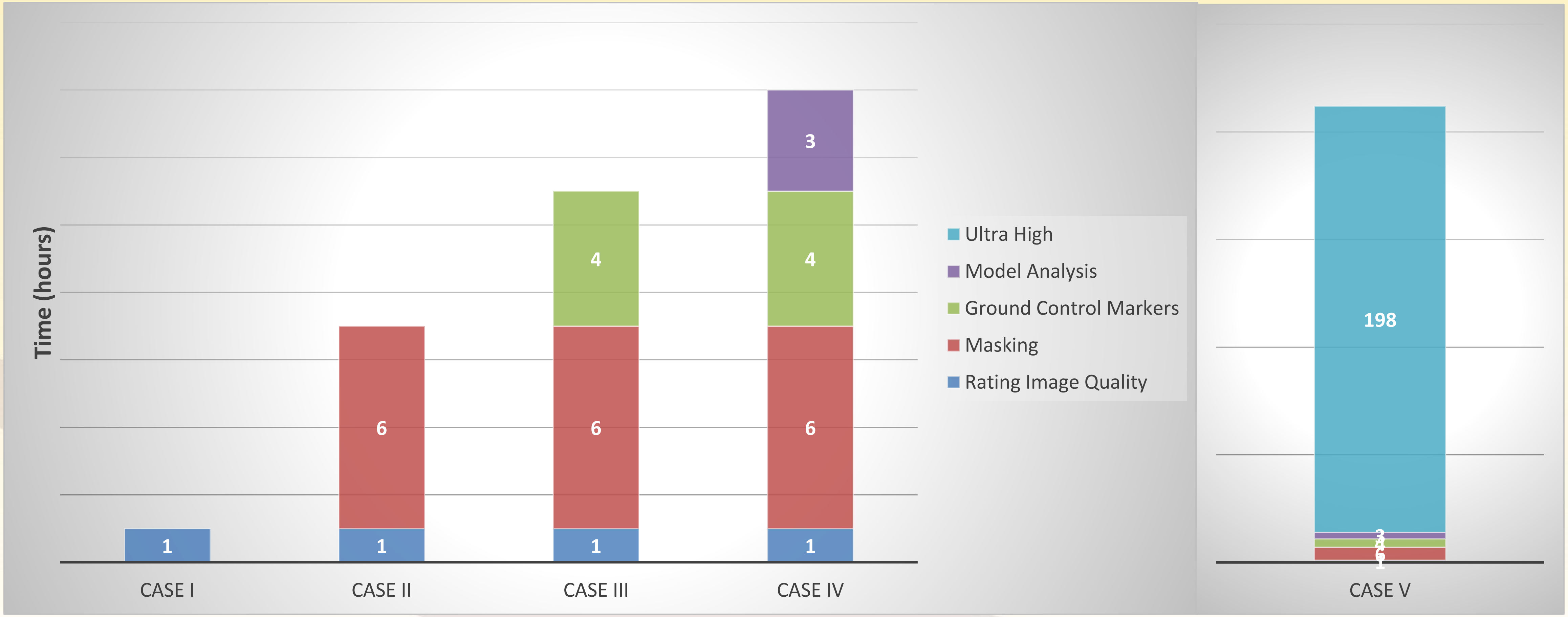
Added Processing Time



*All time estimation based on a picture sample size of 500 photos

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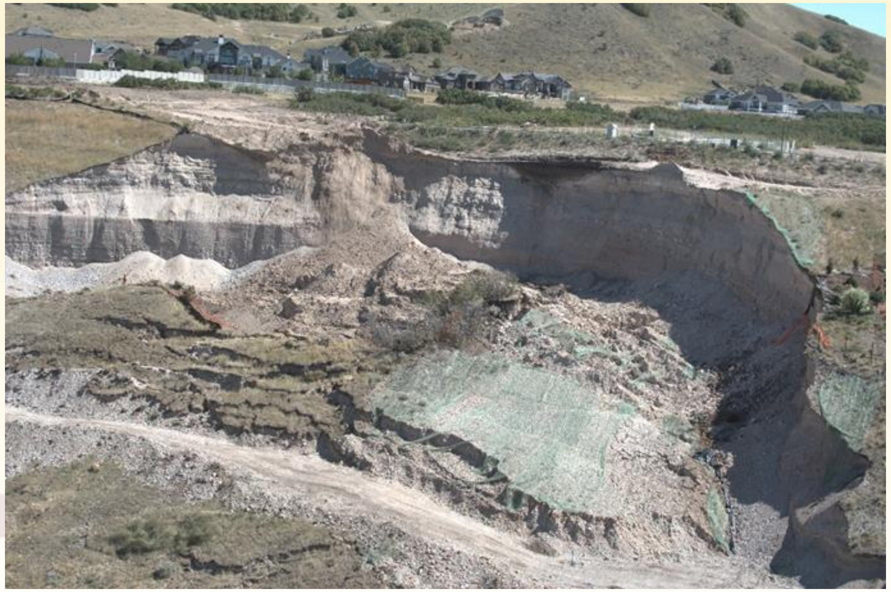
New Study Plan

- When studying US89 in Arizona, different platform and camera combinations were tested and compared
- There are several additional processing parameters that can be tested in order to improve accuracy of models
- Three processing parameters will be compared in the new study of the North Salt Lake landslide
- The new study will determine the most accurate model based on density and ground nearest distance to ground truth LiDAR



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Study Matrix

	No GPS		Ground Control		Camera GPS		Ground Control and Camera GPS	
	No masking	Masking	No Masking	Masking	No Masking	Masking	No Masking	Masking
Processing Quality	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
	High	High	High	High	High	High	High	High

- **Objective** - Take what we learn and quantify and understand the contribution of each processing technique to the accuracy of the model
  - 16 models comparing processing factors

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Conclusions/Recommendations

Based on these results, we believe:

- Model quality and accuracy are significantly improved
- Improvements in accuracy limited by photo quality (motion blur, etc.)
- Accuracy an upper limit when using non-georeferenced imagery
- Both hardware choices and processing methods should be optimized for a given project

Next six months, we will:

- Use camera-mounted GPS to overcome apparent accuracy limits
- Implement new low-cost, light-weight LiDAR sensors, and compare results to SfM output
- Perform a study to quantify the relative influence of flight path, camera-mounted GPS, surveyed GPS control points, and various processing parameters

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Beyond this project…

Model Information Extraction

- Automated identification of materials and objects
- Applications to:
  - Geologic formations
  - Pipeline monitoring
  - Levee monitoring
  - Other large scale infrastructure

Sensor Fusion

- Leverage SLAM for improved SfM
- Automated ground control point acquisition
- Combining strengths of LiDAR, hyperspectral, and E/O sensors
- Optimal flight paths for multi-sensor missions
- Multi-scale modeling and detection