PhotoSat
Leaders in Satellite Surveying for Mining and Energy
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PhotoSat WorldView-3 stereo satellite surveying accuracy study, Garlock Fault, California, 1 GCP, RMSE 13cm

- **146km^2 surveyed using only one ground reference survey point**
- **This WorldView-3 satellite elevation survey is accurate to 13.3 cm RMSE, determined by comparison to 6,854 elevation check points from a highly accurate LiDAR survey**
- **November, 2014 WorldView-3 stereo satellite photos processed by PhotoSat in August, 2016**

Gerry Mitchell, P. Geo, Geophysicist, President PhotoSat
August, 2016

A 1m grid of elevation values, covering an area of 146 square kilometres, was produced over a PhotoSat test area in California. The elevation grid was made using geophysical processing of 50cm ground resolution stereo satellite photos taken by the DigitalGlobe WorldView-3 satellite. The stereo satellite elevation processing was referenced to one ground survey point. The elevation surveying accuracy was determined by direct comparison to 6,854 elevation checkpoints extracted from a highly accurate LiDAR survey.

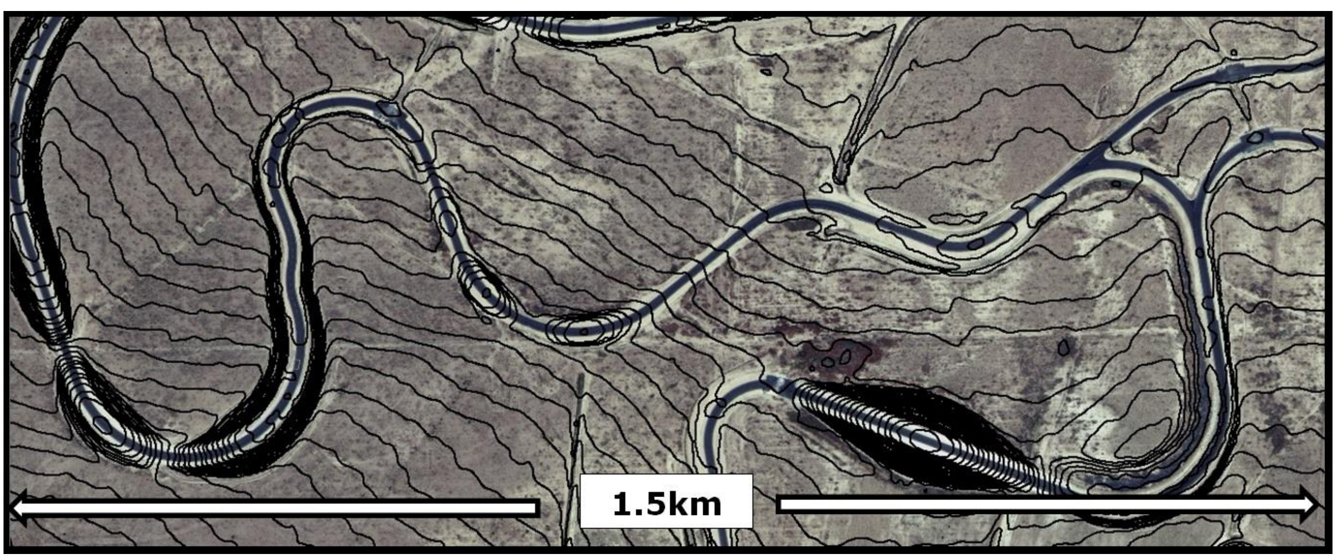

Figure 1. WorldView-3 color image with 50cm contours from the PhotoSat WorldView-3 survey of the California test area.

The Garlock Fault was surveyed with a LiDAR in April 2008 by [OpenTopography](). The location of the LiDAR survey and the area of this WorldView-3 stereo satellite survey accuracy study is shown in Figure 3. We believe this LiDAR survey to be accurate to 5cm RMSE.

Figure 2. The Garlock Fault OpenTopography LiDAR survey shown on Google Earth. The Garlock Fault LiDAR survey was flown in April, 2008. The location of the WorldView-3 stereo satellite photos, acquired November 28, 2014, is shown by the circle.

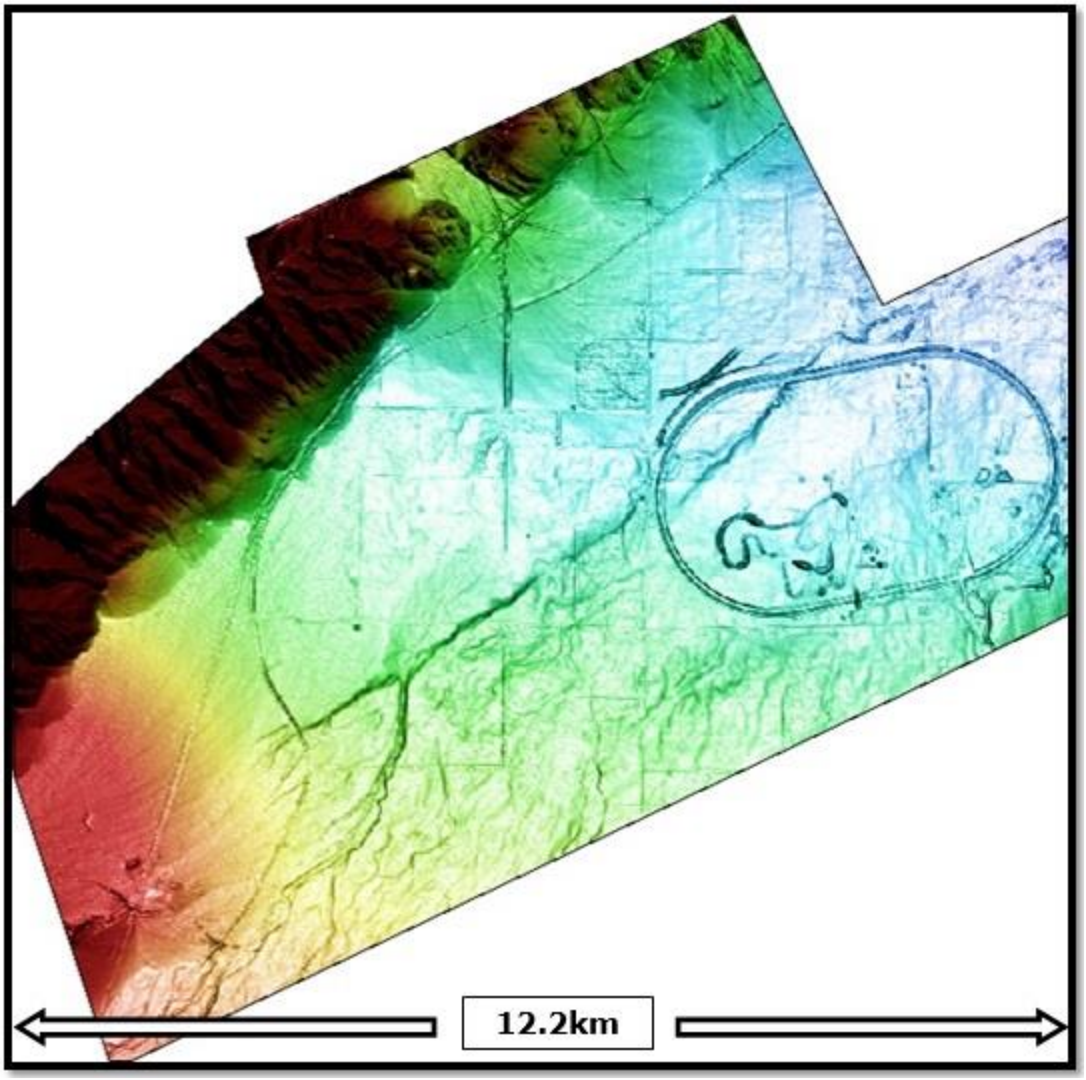

Figure 3. An elevation image showing the portion of the OpenTopography.org LiDAR survey used in this accuracy study. The dimensions of the area are 12.2km east–west by 12km north–south. Lower elevations are blue and higher elevations are red. The oval is the Honda California Test Track.

Stereo satellite photos:

PhotoSat satellite surveying uses high quality stereo satellite photos. These photos are taken by the satellite as it passes over the survey area along a north to south satellite orbit. The process of taking the stereo photos is illustrated in Figure 2.

The satellite photographs the same ground area within a minute or two, so the ground conditions are close to identical in each photo. The difference in appearance of ground features on the photos is due to the different look directions of the satellite camera.

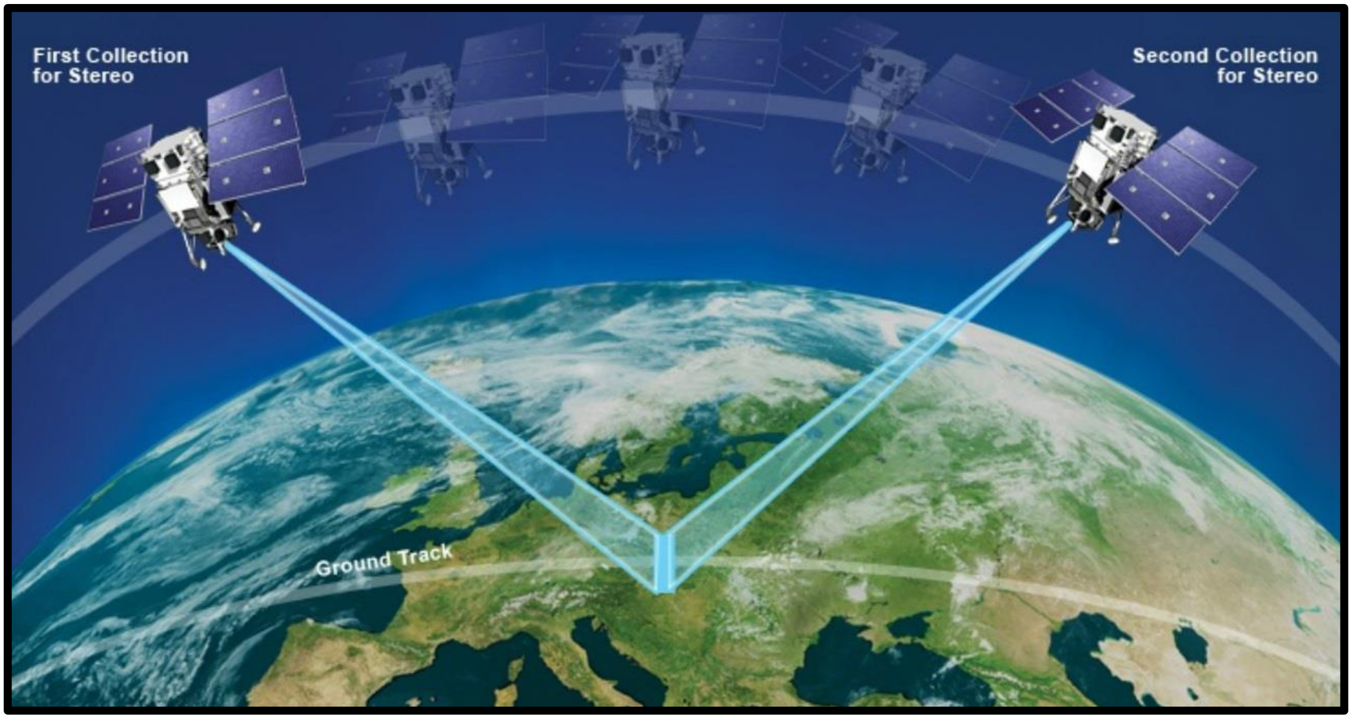

Figure 4. Illustration showing the process of taking satellite stereo photos. The satellite points forward to take the first photo. About one minute later, and 300km further along its orbital track, the satellite rotates to take the second photo looking backwards along the track. Hundreds of km^2 can be accurately surveyed with a single pair of stereo satellite photos.

PhotoSat Geophysical Stereo Satellite Processing System:

Survey coordinates of ground features are determined by measuring the apparent shift in location of the features between the two satellite photos. PhotoSat uses a proprietary geophysical processing system to generate survey coordinates from stereo satellite photos. This system is described in a PhotoSat white paper published at a 2010 ASPRS conference.

Figure 5. WorldView-3 satellite photos of PhotoSat's California test area taken on November 28, 2014 at approximately 11:30 AM local time. The photo on the left was taken looking at an azimuth of 239 deg and angle from vertical of 24 deg. The photo on the right was taken looking at an azimuth of 339 deg and angle from vertical of 31 deg. The arrows on the photos indicate the satellite look direction. The lengths of the arrows are proportional to the look angles from vertical. This stereo pair has a convergence angle of 42 deg, a bisector azimuth of 117 deg and bisector angle of 19 deg from vertical.

California satellite photos:

The pair of stereo WorldView-3 satellite photos over the California test area are shown in Figure 5. The photos were taken on November 28, 2014 at approximately 11:30 AM local time. The stereo satellite photo look directions, convergence angle, bisector azimuth and bisector angle from vertical are shown in the figure caption. The convergence angle of 42 deg is optimum for surveying elevations in level to moderate terrain.

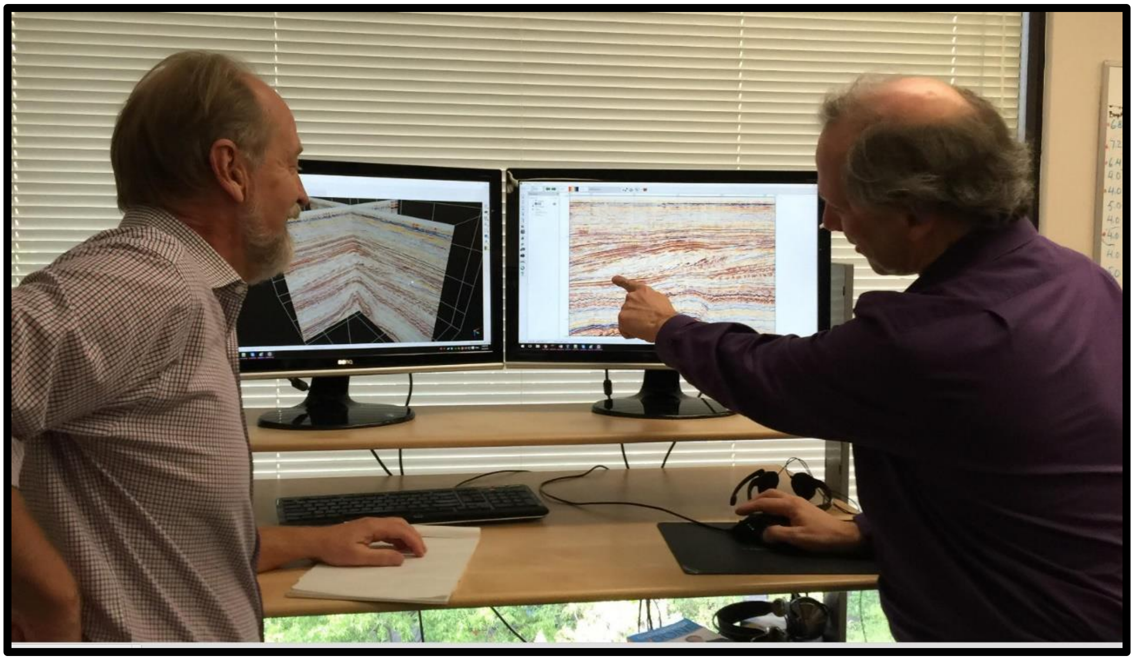

Figure 6. Gerry Mitchell, left and Michael Ehling with an Oil and Gas seismic processing workstation. This technology is the basis for the PhotoSat geophysical stereo satellite processing system named the PhotoSat Process Manager.

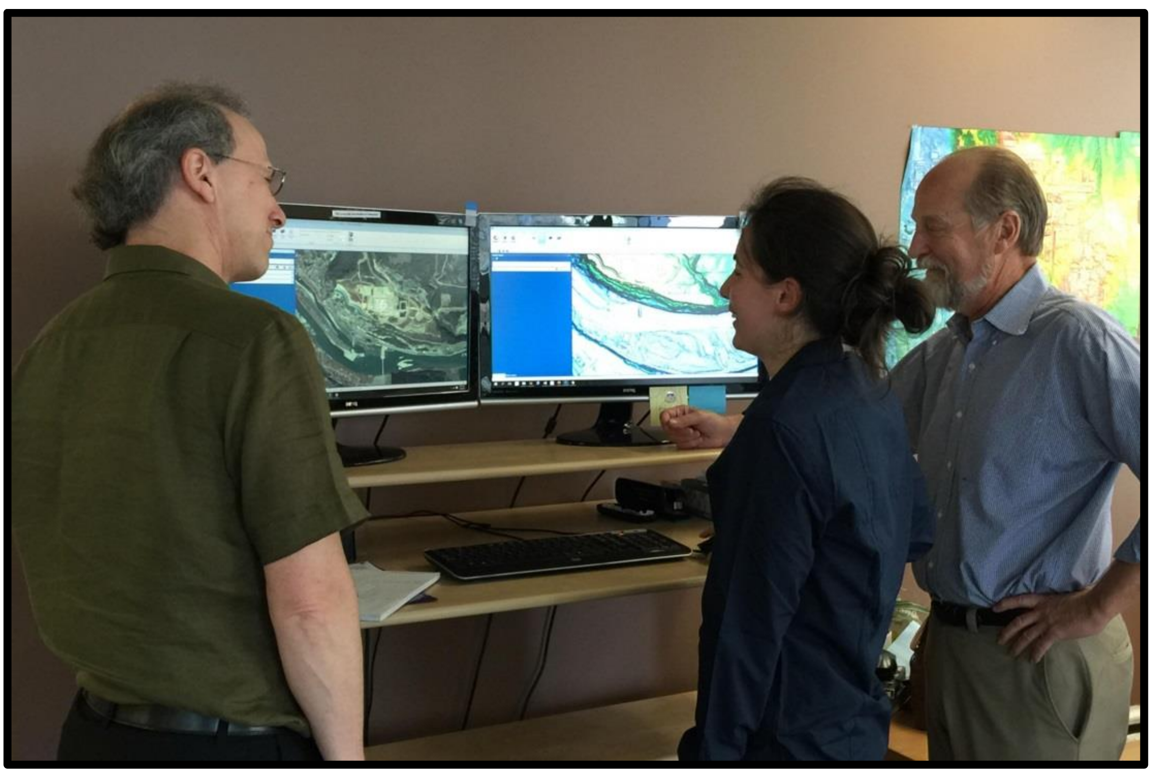

Figure 7. Michael, Gerry and Jayda Akatsuka with the PhotoSat Process Manager.

Figure 8. WorldView-3 50cm resolution orthophoto, created from the WorldView-3 stereo photos, for the area of the LiDAR survey used in this study. The 7.5 mile oval track is the Honda California Test Track. The single ground reference point is shown as a white cross.

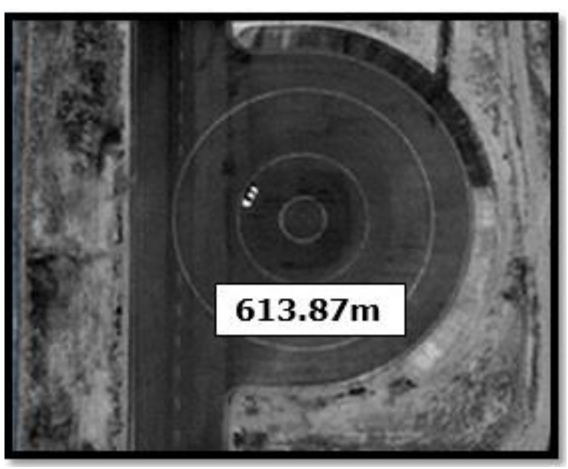

Figure 9. Ground reference point used for the Honda California Test Track area.

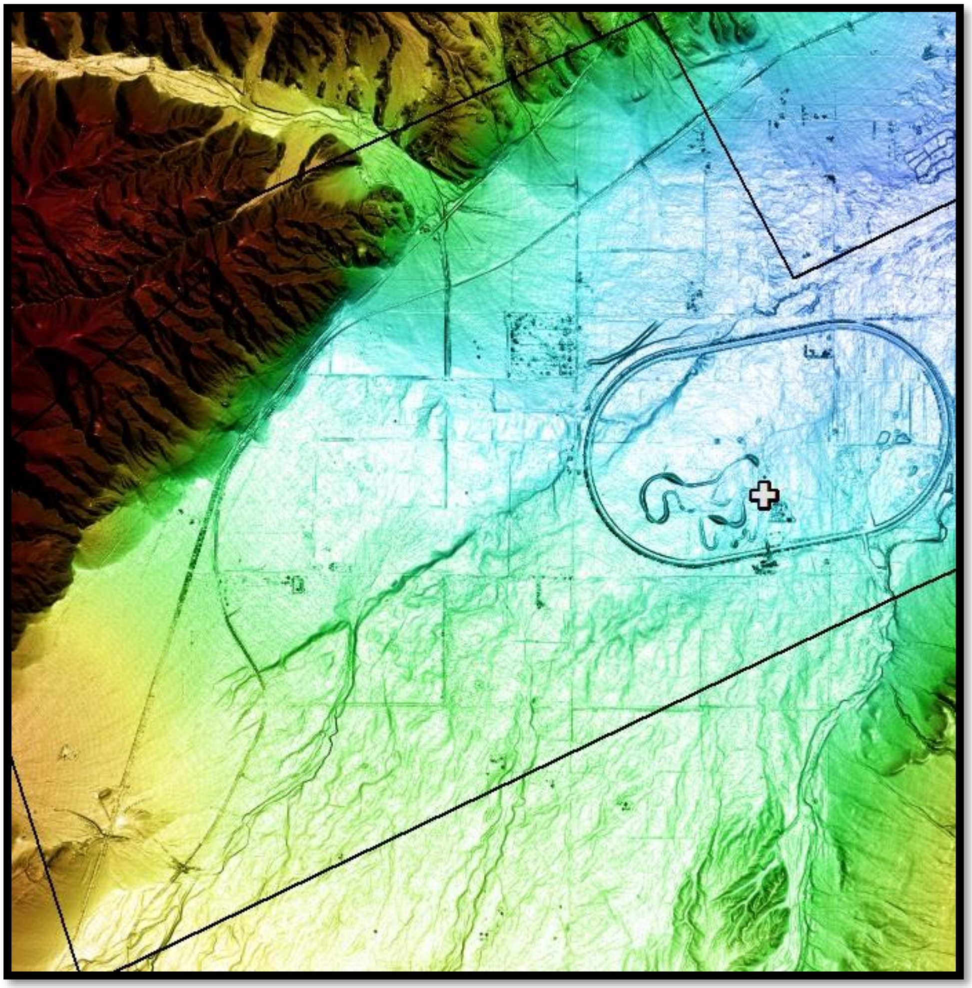

Figure 10. Stereo WorldView-3 elevation image covering the area of the LiDAR image in Figure 3. This elevation grid has an elevation point every meter. At this scale, the LiDAR and WorldView-3 images are identical. Low elevations are blue and high elevations are red.

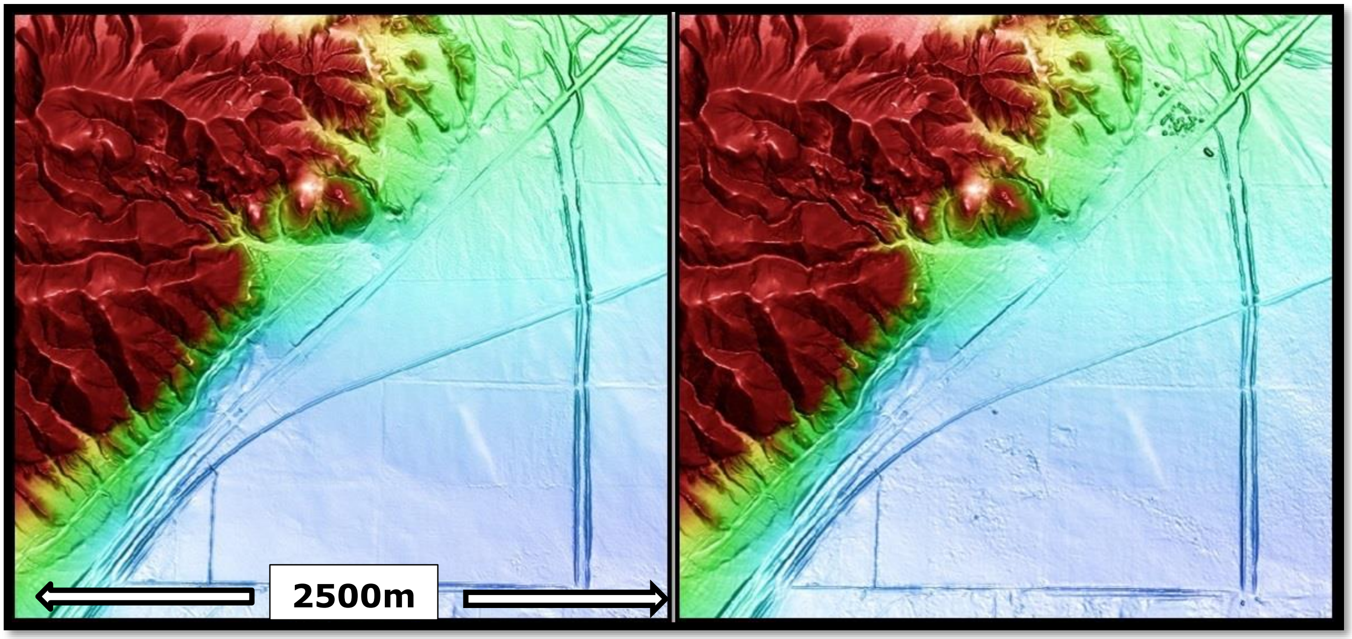

Figure 11. Comparison of the elevation grids between the LiDAR on the left and the stereo WorldView-3 on the right. This is for a 2,500m wide area. Minor differences between the elevation grids are visible at this scale.

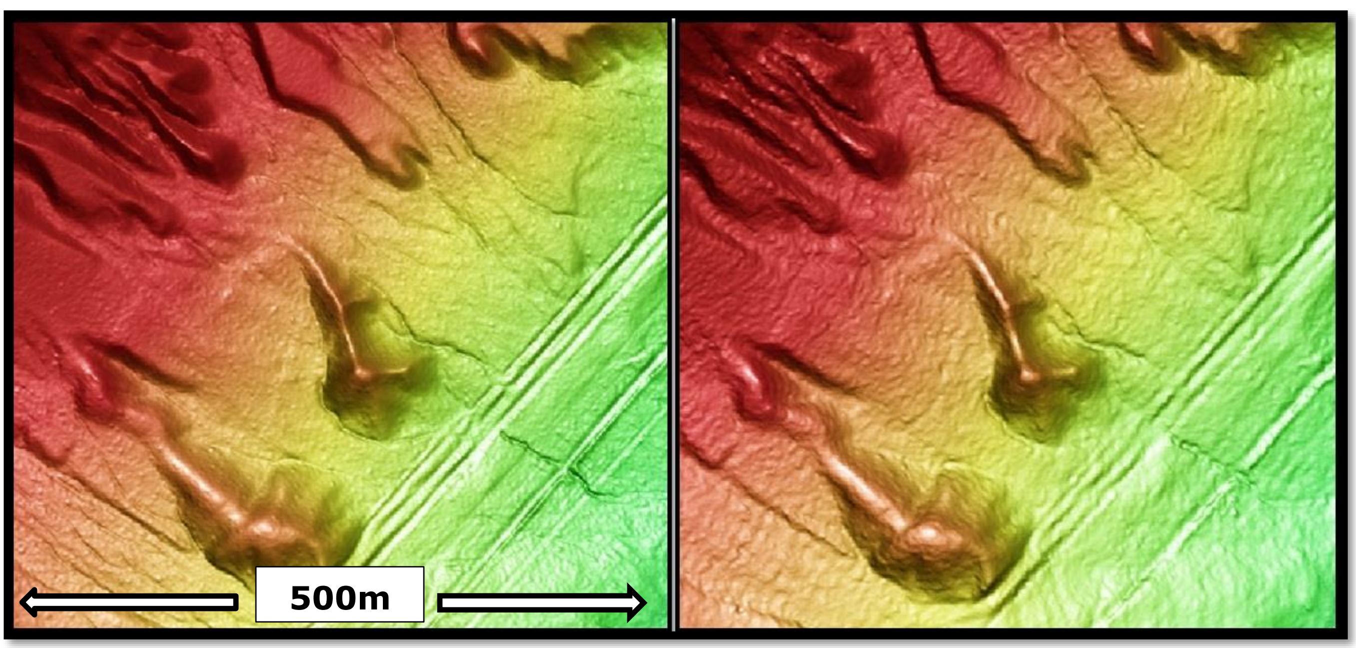

Figure 12. Comparison of the elevation grids between the LiDAR on the left and the stereo WorldView-3 on the right. This is for a 500m wide area. More topographic detail is visible on the LiDAR at this scale.

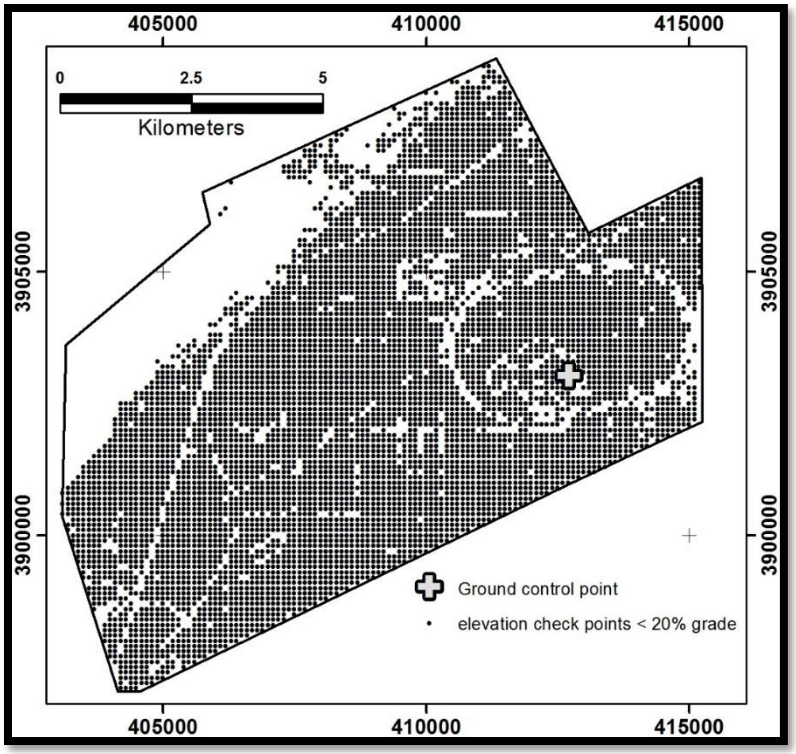

Figure 13. Elevation checkpoints for areas with slopes of less than 20% grade.

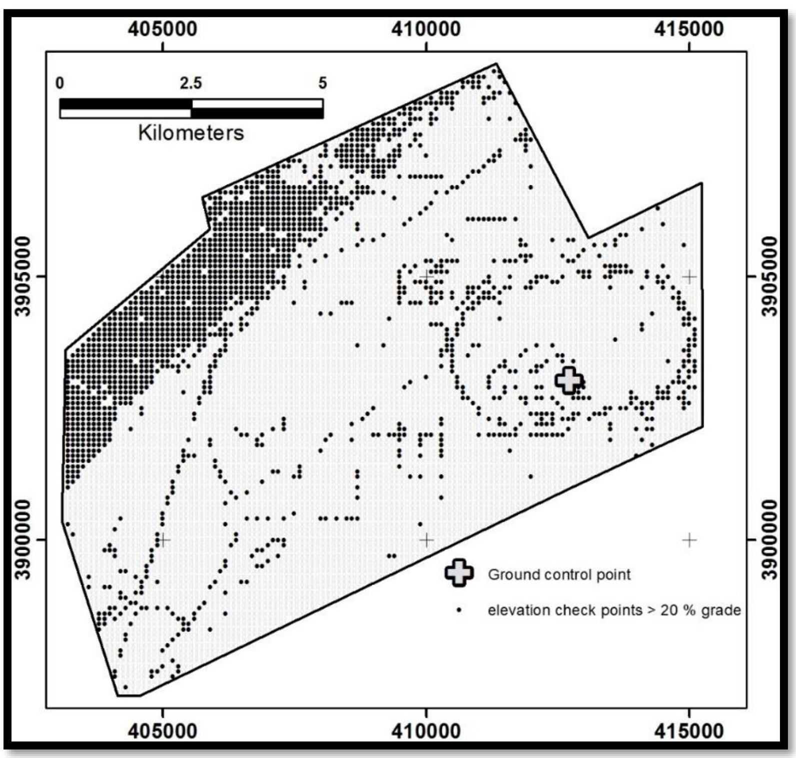

Figure 14. Elevation checkpoints for areas with slopes of greater than 20% grade.

California elevation grid:

PhotoSat produced a 1m grid of elevations over the entire project area. We processed the stereo WorldView photos with our geophysical stereo satellite processing system in August, 2016. An image of the 1m elevation grid is shown in Figure 10.

Ground reference points:

With this accuracy study we are demonstrating that we can produce highly accurate WorldView-3 surveys with only one ground reference point. Having as few as one ground reference survey point for a 146 km^2 satellite surveying project is not uncommon in mining exploration projects.

The location of the ground reference point is shown in Figure 8.

Global shift of stereo satellite survey to match ground reference:

The WorldView ortho photo and elevation grid needed a constant shift of only 1.3m E, 0.90m N and -0.94m in elevation to match the ground surveying. The global accuracy of most WorldView stereo satellite photos is better than 3m.

Accuracy evaluation checkpoints:

The accuracy of the PhotoSat 1m survey grid was evaluated with 6,854 elevation checkpoints derived from the LiDAR elevation grid.

Elevation survey accuracy statistics:

The *Guidelines for Digital Elevation Data* of the US National Digital Elevation Program (NDEP) recommends that elevation checkpoints should be chosen in areas with slopes less than 20% grade. The 6,854 elevation checkpoints with slopes less than 20% grade have an RMSE of 13cm as shown in Figure 15.

The points on slopes over 20% grade have an RMSE of 21cm as shown in Figure 16.

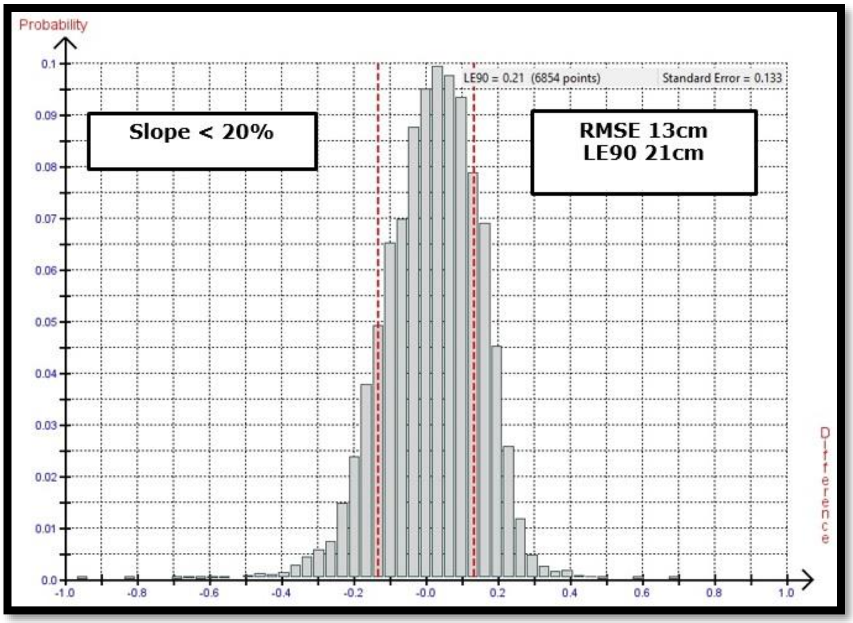

Figure 15. Histogram of the elevation differences between the WorldView-3 stereo satellite elevations for the 12.2km by 12km area and the 6,854 elevation checkpoints with slopes less than 20% grade. The *Guidelines for Digital Elevation Data* of the US National Digital Elevation Program (NDEP) recommends that elevation checkpoints should be chosen in areas with slopes less than 20% grade. RMSE 13cm, LE90 21cm.

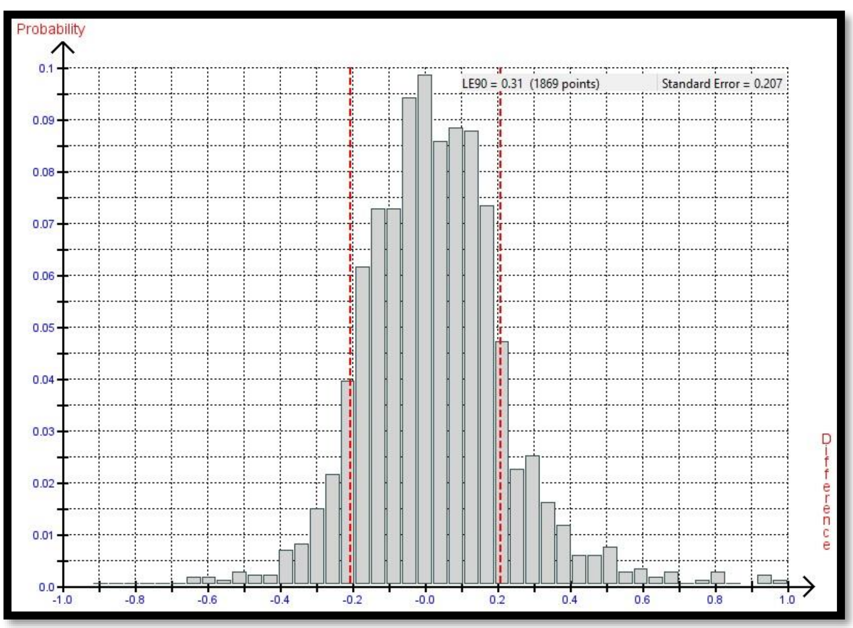

Figure 16. Histogram of the elevation differences between the WorldView-3 stereo satellite elevations for the 12.2km by 12km area and the 1,869 elevation checkpoints with slopes between 20% and 100% grade. RMSE 21cm, LE90 31cm.

Cautionary Statement:

This is an accuracy assessment for elevation mapping from a single stereo pair of WorldView-3 satellite photos. While in our experience these results are typical for most WorldView-3 stereo photos, these results may not apply to any specific pair of WorldView-3 stereo photos.

References:

A Geophysical Stereo Satellite Elevation Mapping System, Mitchell G & Ehling M, ASPRS 2010 Annual Convention, San Diego, California, USA
http://www.photosat.ca/pdf/asprs_geophysical_mapping_system_2010.pdf

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http://www.ndep.gov/NDEP_Elevation_Guidelines_Ver1_10May2004.pdf