

PhotoSat WorldView-2 stereo satellite surveying accuracy study, Garlock Fault, California, 153 GCP, 12cm RMSE

- **174km² surveyed using 153 ground reference points**
- **This WorldView-2 satellite elevation survey is accurate to 12cm RMSE, determined by comparison to 7,414 elevation check points from a highly accurate LiDAR survey**
- **April, 2010 WorldView-2 stereo satellite photos processed by PhotoSat in August, 2016**

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A 1m grid of elevation values, covering an area of 174 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-2 satellite. The stereo satellite elevation processing was referenced to 153 ground reference points extracted from the LiDAR data. The elevation surveying accuracy was determined by direct comparison to 7,414 elevation checkpoints extracted from a highly accurate LiDAR survey.

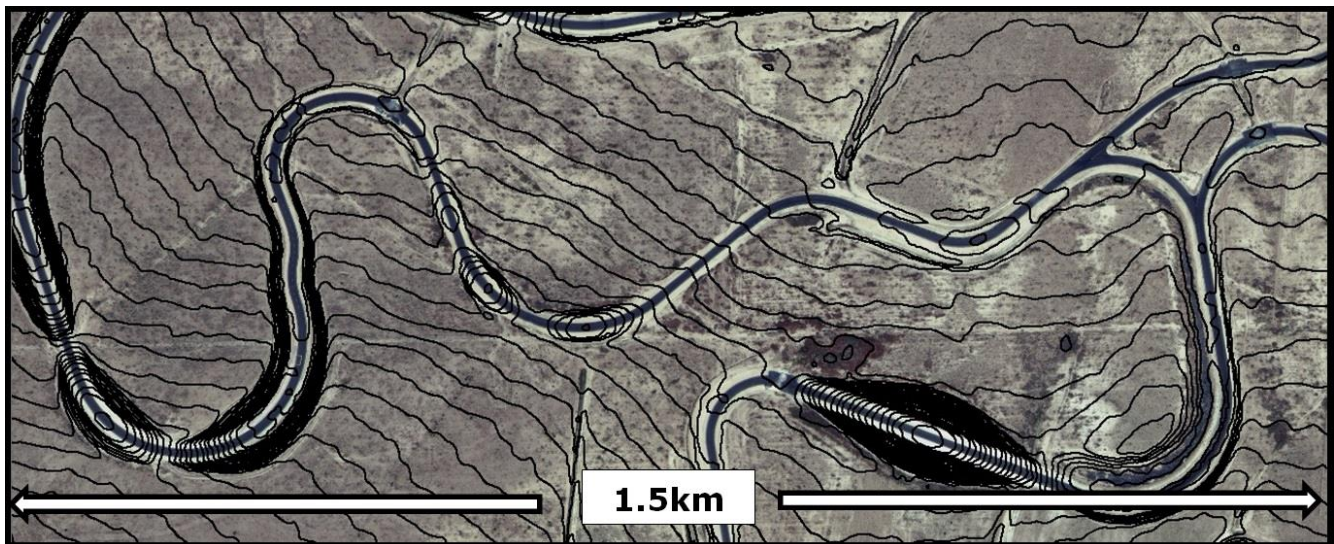


Figure 1. WorldView-2 color image with 50cm contours from the PhotoSat WorldView-2 survey of the California test area.

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-2 stereo satellite survey accuracy study is shown in Figure 2. We believe this LiDAR survey data to be accurate to better than 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-2 stereo satellite photos, acquired April 29, 2010, is shown by the circle.

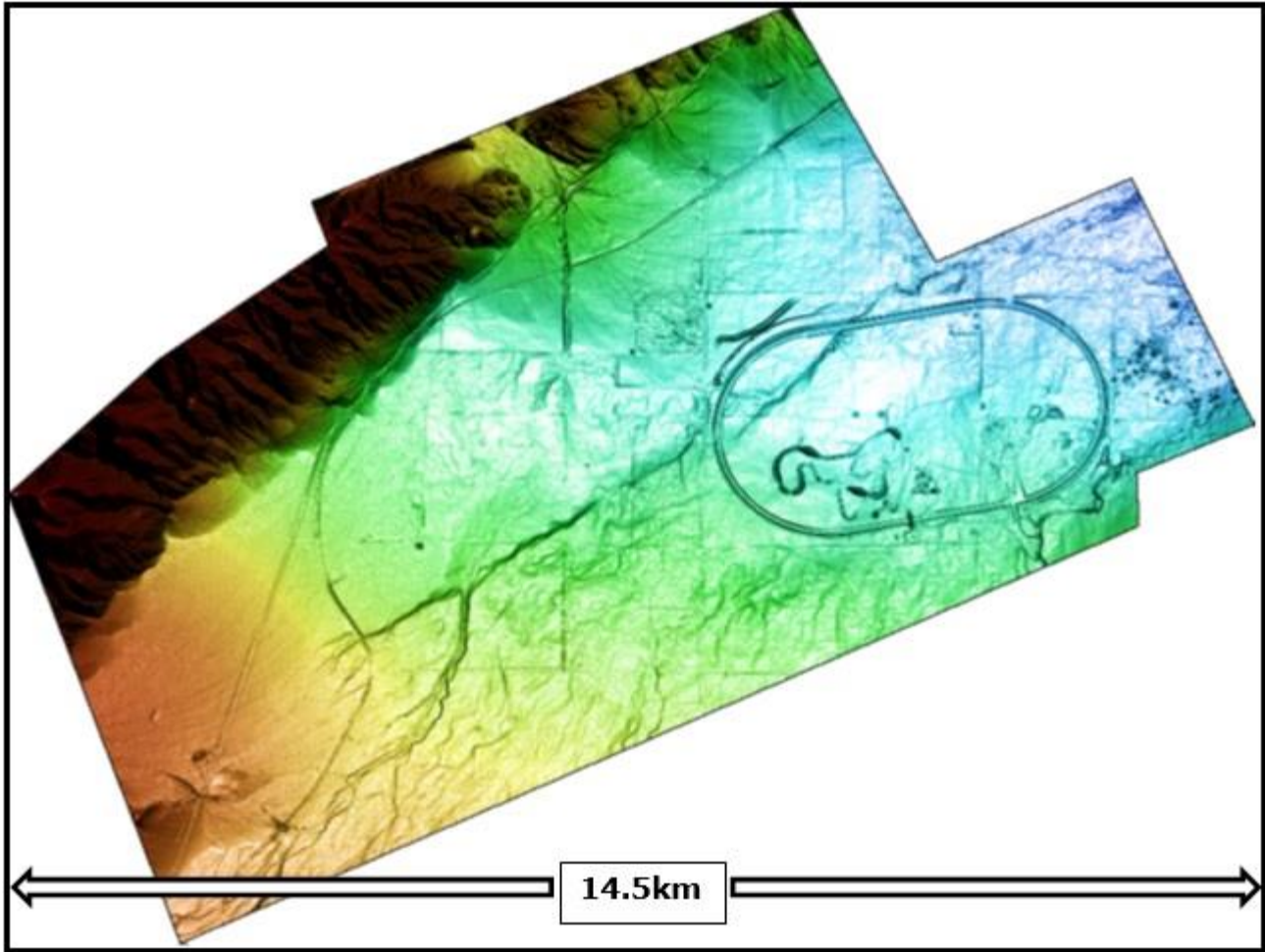


Figure 3. An elevation image showing the portion of the Opentopography.org LiDAR survey used in this accuracy study. The dimensions of the area are 14.5km east–west by 12km north–south. Lower elevations are blue and higher elevations are red. The oval is the Honda California Test Track.

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 on the two photos. The difference in appearance of ground features on the photos is due to the different look directions of the satellite camera.

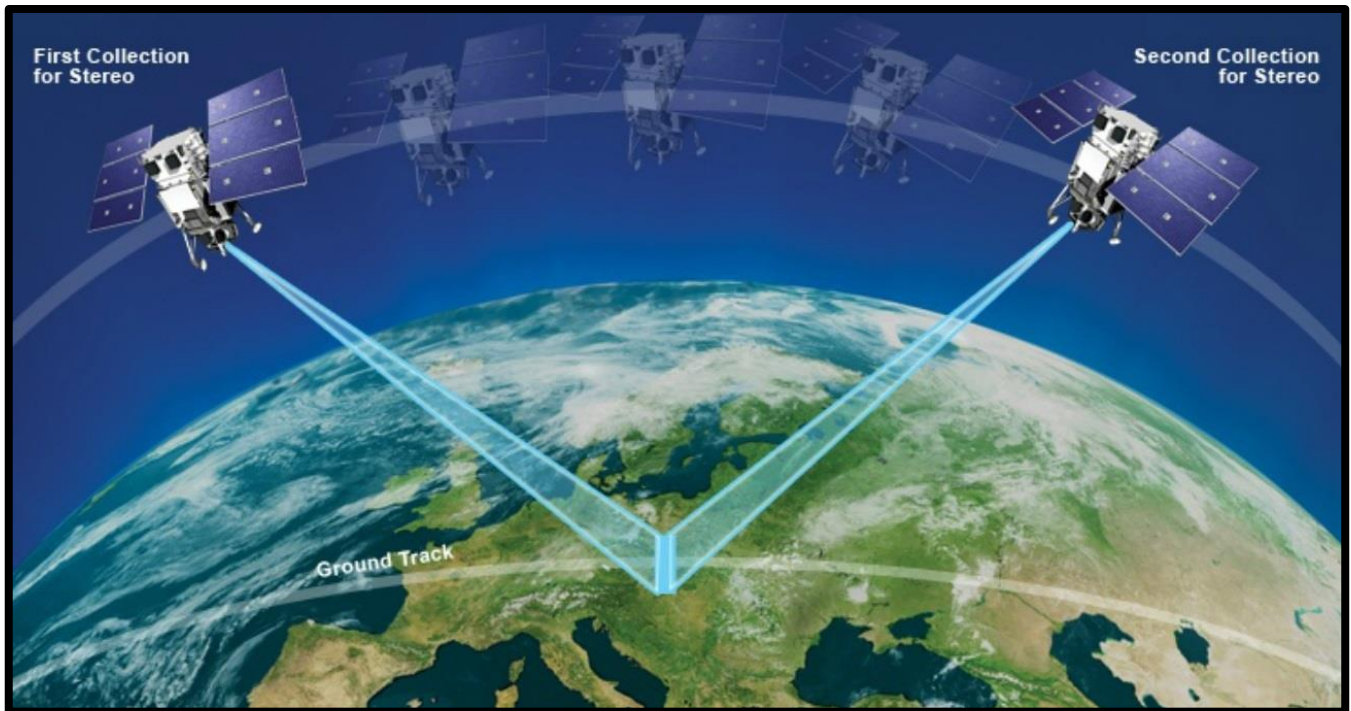


Figure 4. Illustration showing the process of taking satellite stereo photos. The satellite points forward to take the first photo. About one minute later, and 300 km further along its orbital track, the satellite rotates to take the second photo looking backwards along the track. Hundreds of km² can 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.

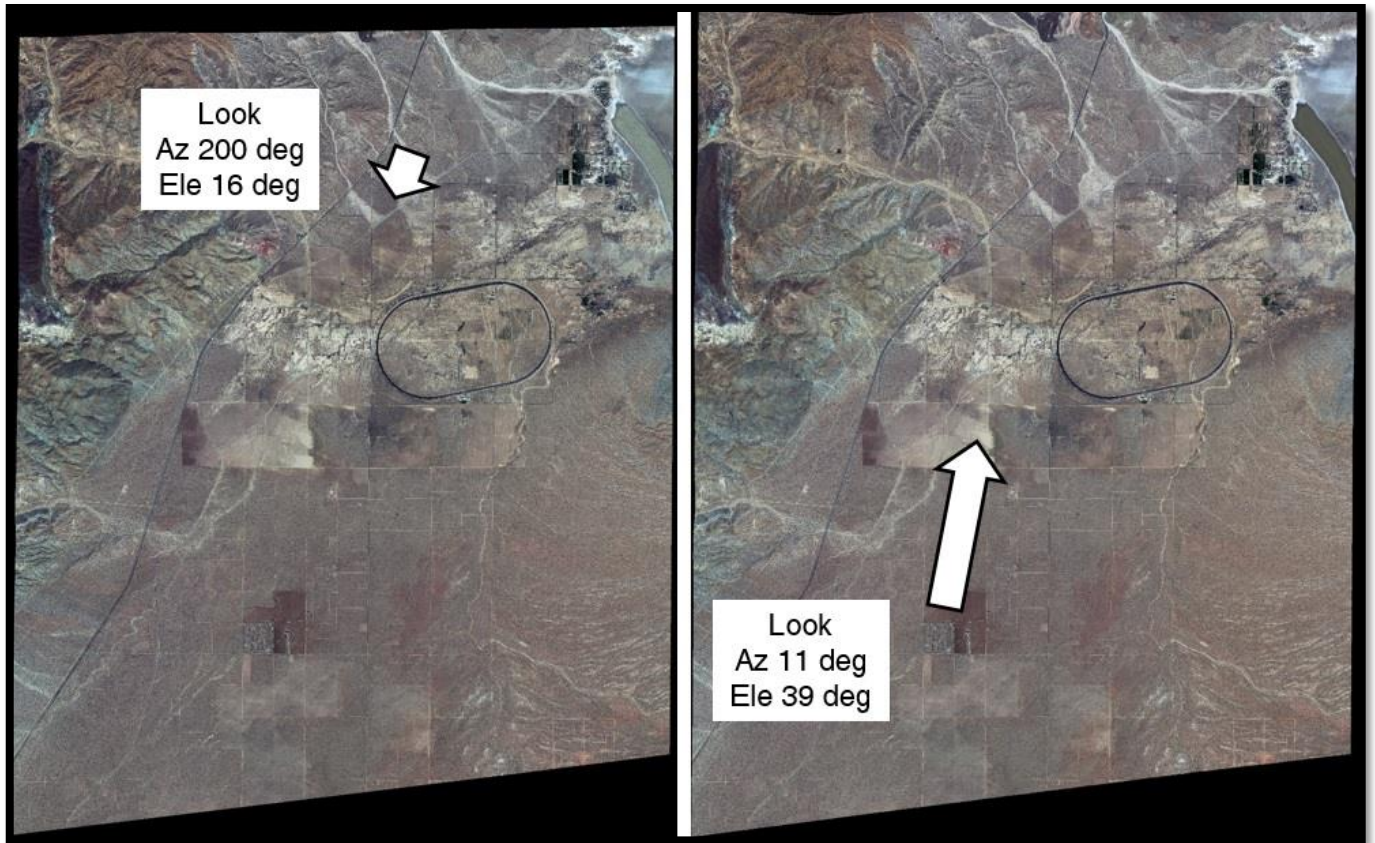


Figure 5. WorldView-2 satellite photos of PhotoSat's California test area taken on April 29, 2010 at approximately 11:50 AM local time. The photo on the left was taken looking at an azimuth of 200 deg and angle from vertical of 16 deg. The photo on the right was taken looking at an azimuth of 11 deg and angle from vertical of 39 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 54 deg, a bisector azimuth of 78 deg and bisector angle of 12 deg from vertical.

California satellite photos:

The pair of stereo WorldView-2 satellite photos over the California test area are shown in Figure 5. The photos were taken on April 29, 2010 at approximately 11:50 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 54 deg is optimum for surveying elevations in level to moderate terrain.

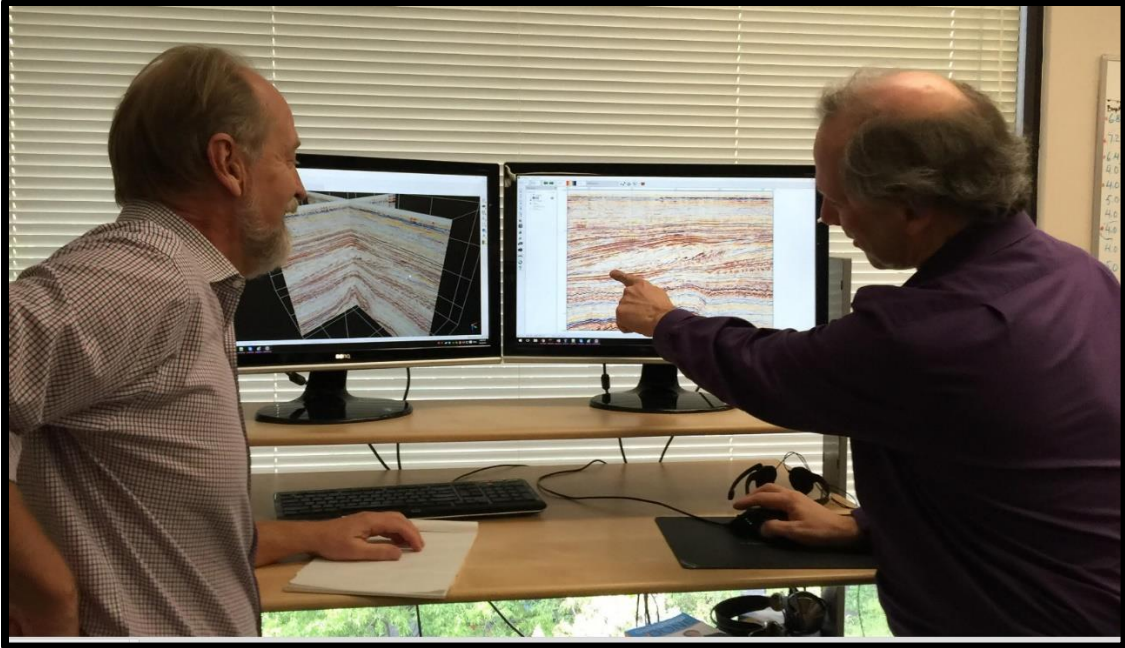


Figure 6. Gerry Mitchell, left and Michael Ehling with an Oil and Gas seismic processing workstation. This technology is the basis for the PhotoSat geophysical stereo satellite processing system named the PhotoSat Process Manager.

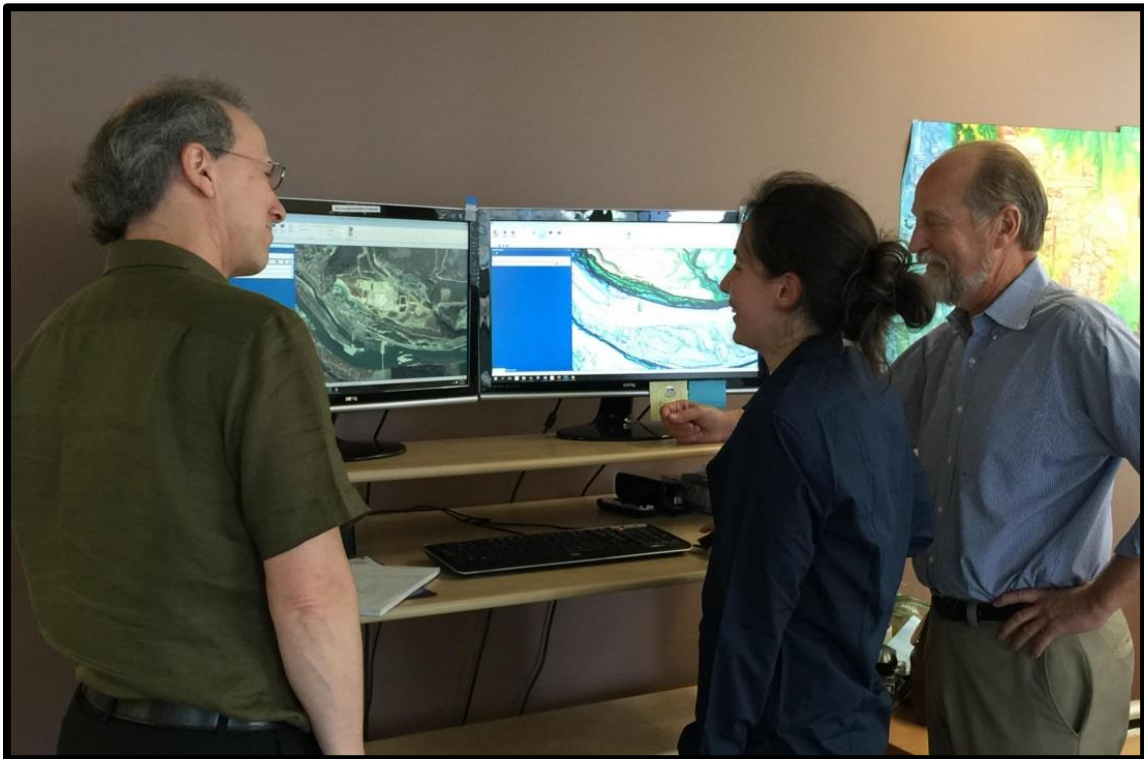


Figure 7. Michael, Gerry and Jayda Akatsuka with the PhotoSat Process Manager.

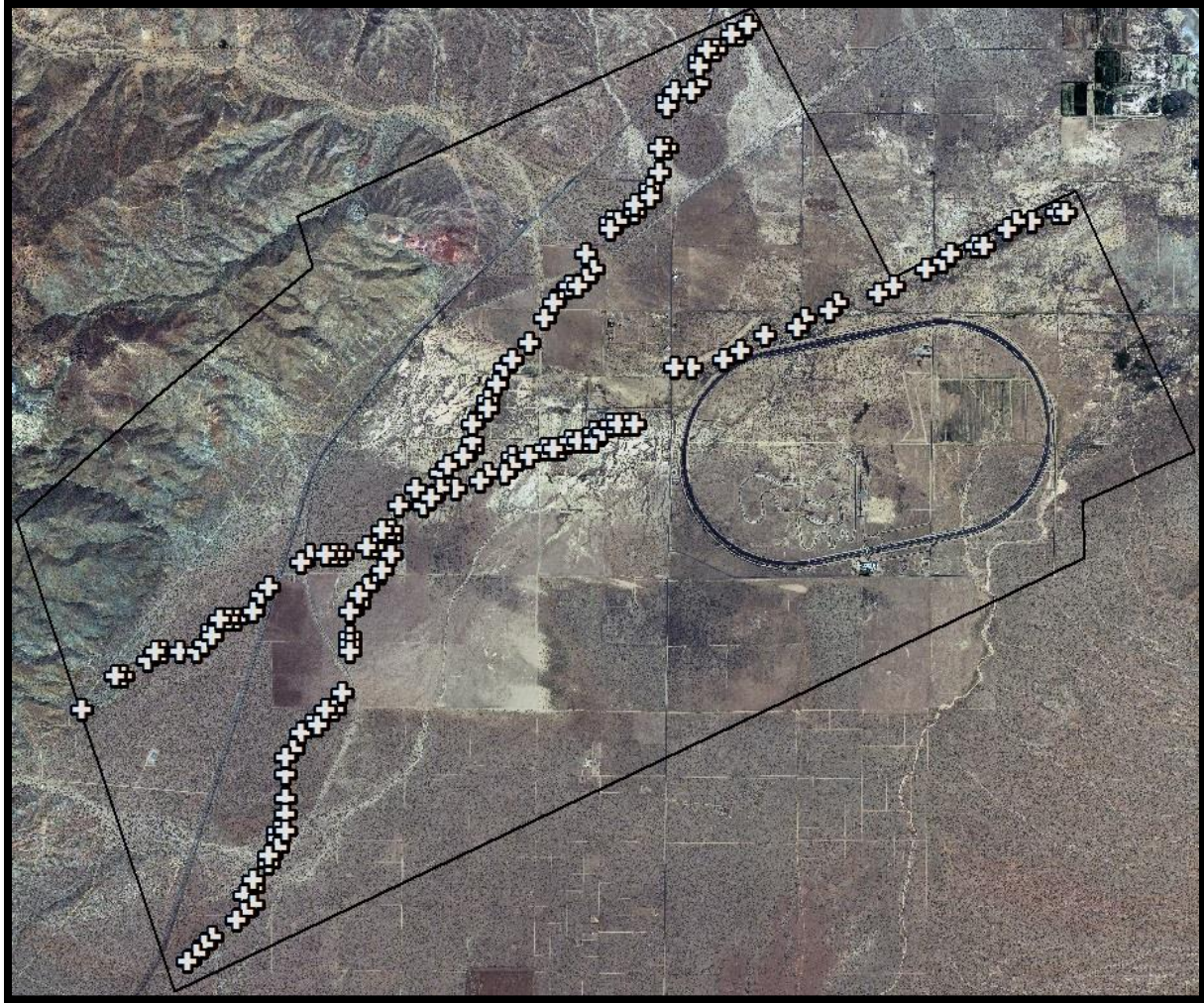


Figure 8. WorldView-2 50cm resolution orthophoto, created from the WorldView-2 stereo photos, for the area of the LiDAR survey used in this study. The 7.5 mile oval track is the Honda California Test Track. The 153 ground reference points are shown as a white crosses. The ground reference points were extracted from the LiDAR survey data. This is typical of the distribution of ground survey points long 2D seismic lines on a typical Oil and Gas exploration project.

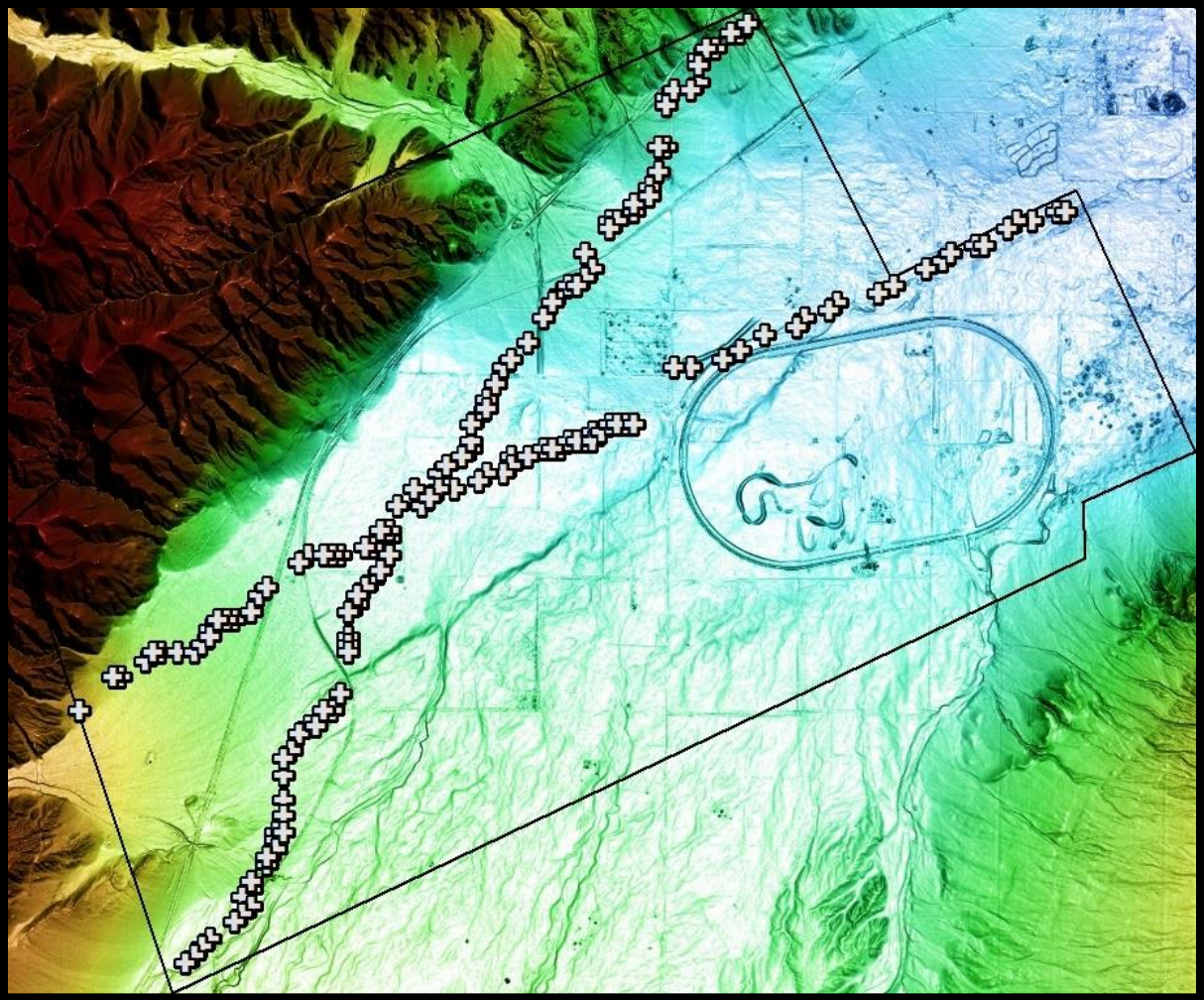


Figure 9. Stereo WorldView-2 elevation image covering the area of the LiDAR image in Figure 3. This elevation grid has an elevation point every meter. At this scale, the LiDAR and WorldView-2 images are identical. Low elevations are blue and high elevations are red.

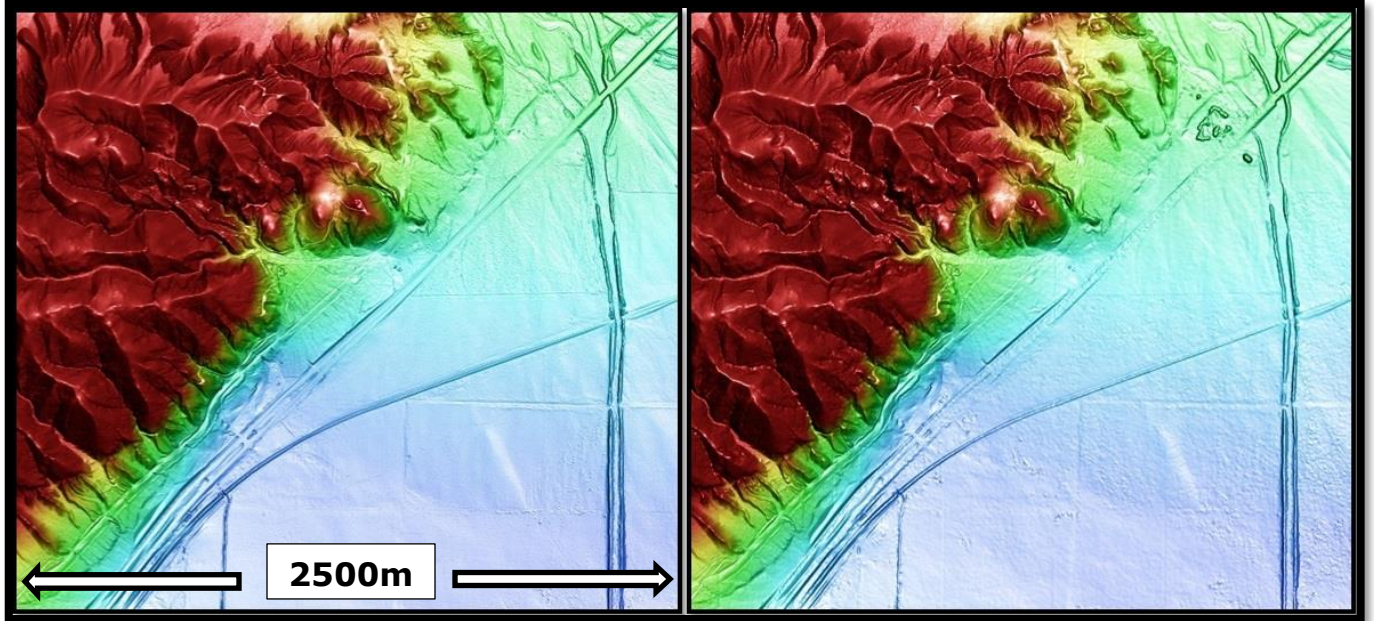


Figure 10. Comparison of the elevation grids between the LiDAR on the left and the stereo WorldView-2 on the right. This is for a 2,500m wide area. Minor differences between the elevation grids are visible at this scale.

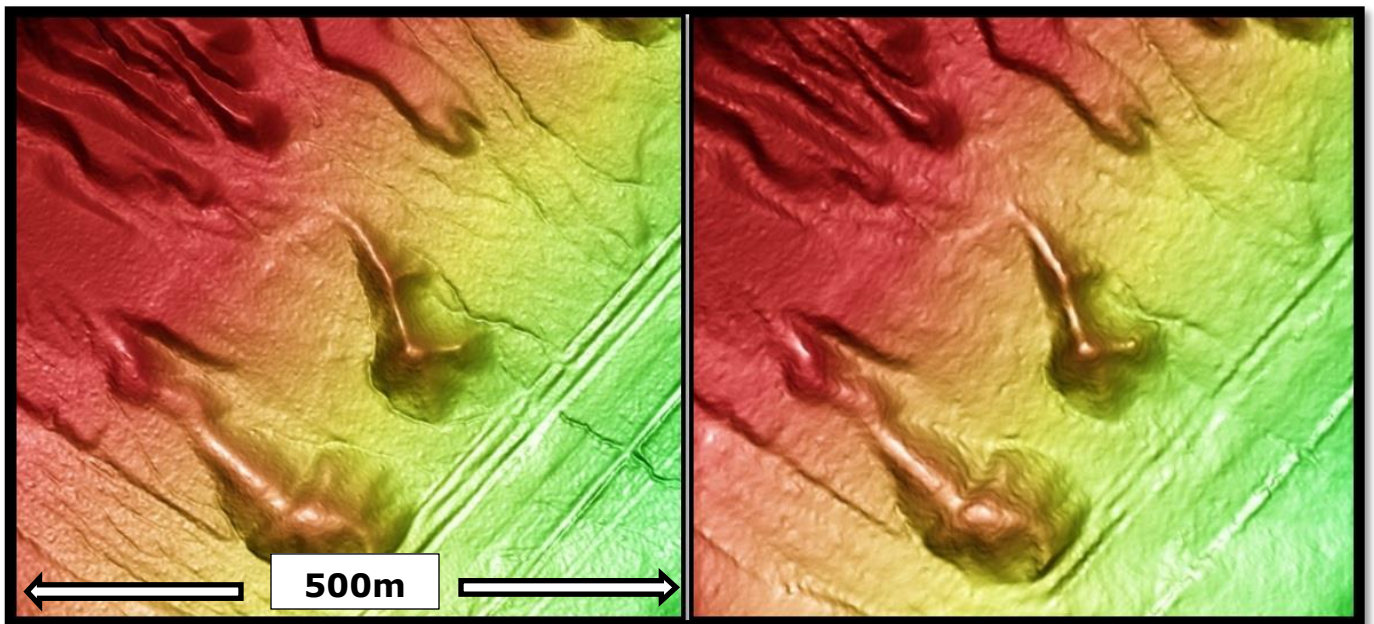


Figure 11. Comparison of the elevation grids between the LiDAR on the left and the stereo WorldView-2 on the right. This is for a 500m wide area. More topographic detail is visible on the LiDAR at this scale.

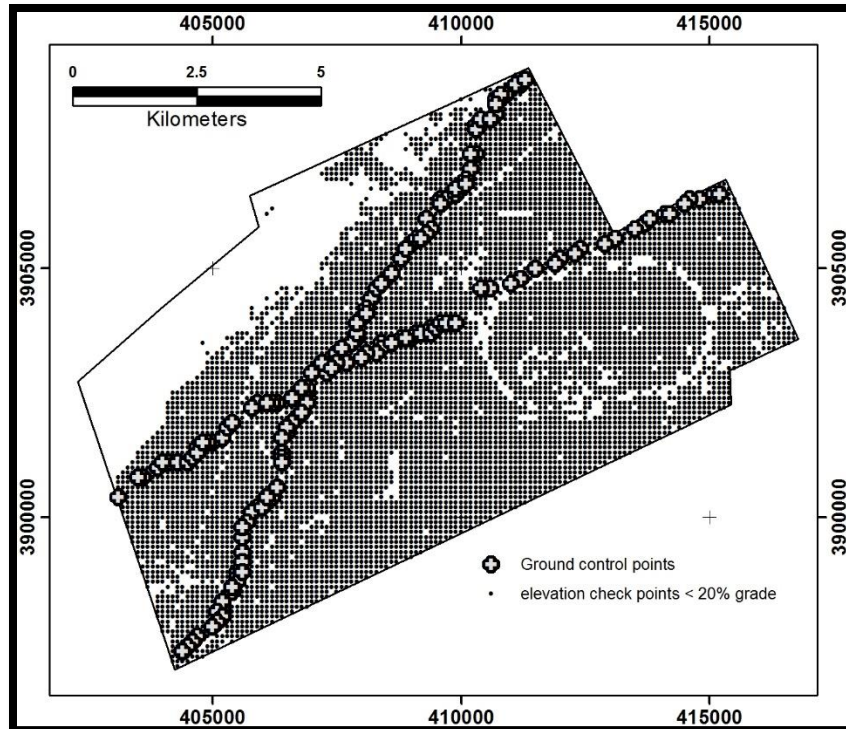


Figure 12. 7,414 elevation checkpoints for areas with slopes of less than 20% grade.

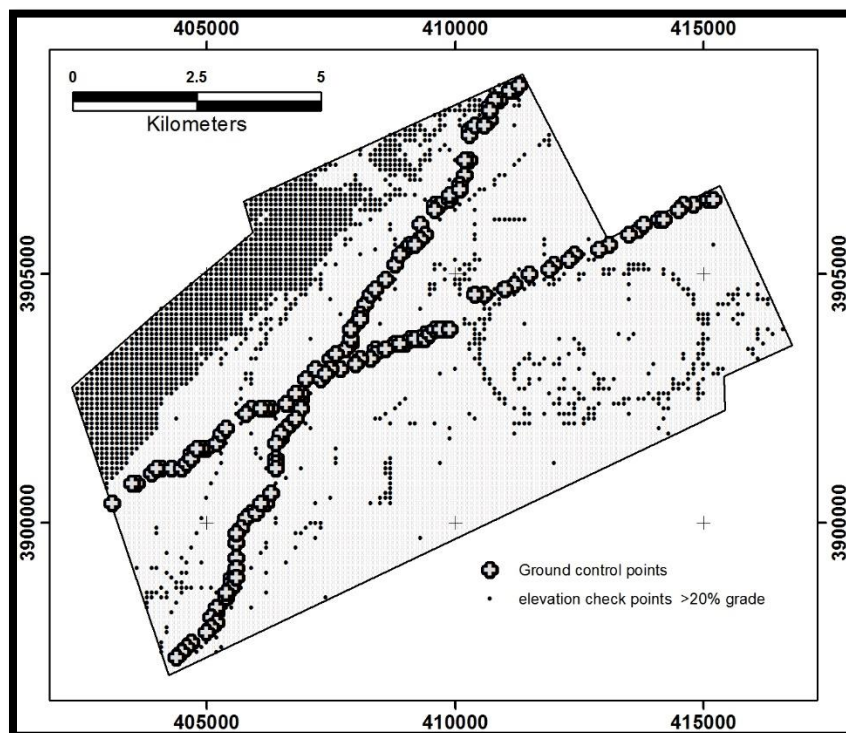


Figure 13. Elevation checkpoints for areas with slopes of greater than 20% grade.

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 study we are demonstrating the satellite surveying accuracy we can produce with stereo WorldView-2 when we have lines of survey points. We extracted a total of 153 survey points over level areas on the LiDAR data. These points lie along two lines as shown in figures 9 and 10. This distribution of survey points is typical of the survey points for source and receiver locations for 2D seismic surveys used in Oil and Gas exploration.

Global shift of stereo satellite survey to match ground reference:

The WorldView ortho photo and elevation grid needed a constant shift of only -0.9m E, 0.8m N and 0.69m 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 7,414 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 7,414 elevation checkpoints with slopes less than 20% grade have an RMSE of 12cm as shown in Figure 14.

The points on slopes over 20% grade have an RMSE of 24cm as shown in Figure 15.

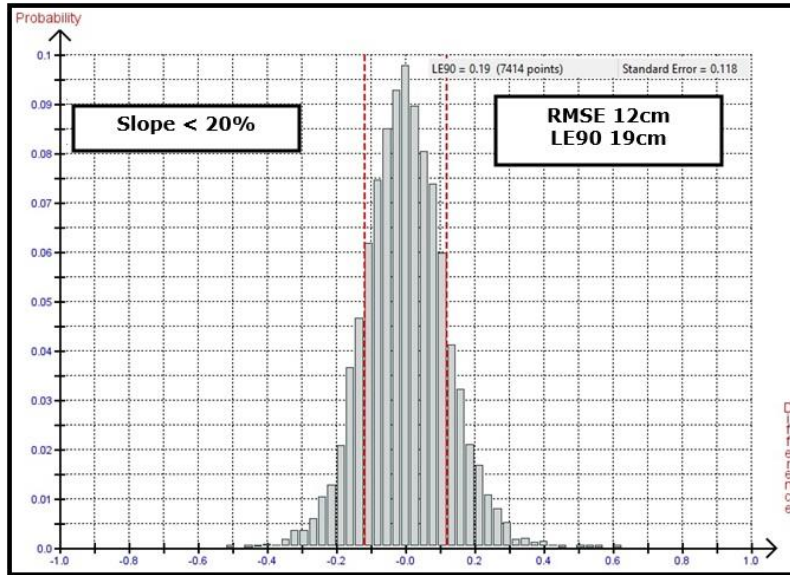


Figure 14. Histogram of the elevation differences between the WorldView-2 stereo satellite elevations for the 14.5km by 12km area and the 7,414 elevation checkpoints with slopes less than 20% grade. The *Guidelines for Digital Elevation Data* of the US National Digital Elevation Program (NDEP) recommends that elevation checkpoints should be chosen in areas with slopes less than 20% grade. RMSE 12cm, LE90 19cm.

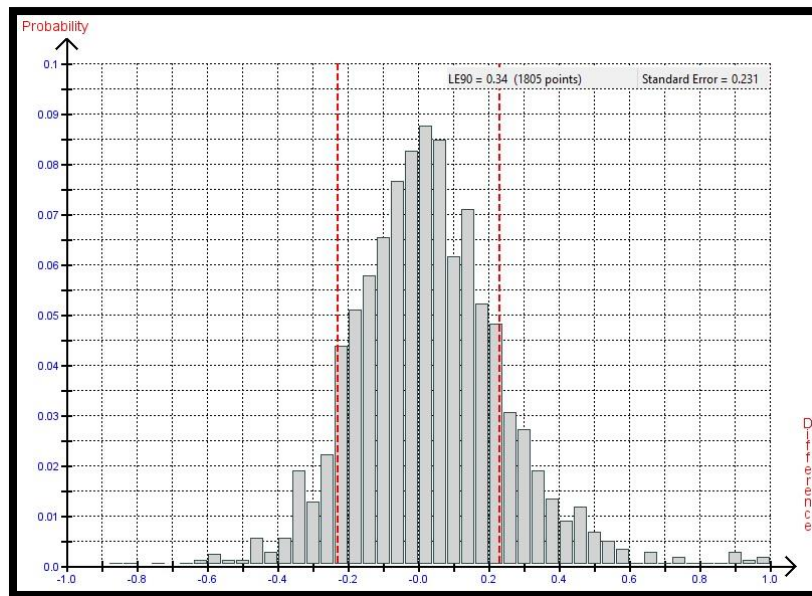


Figure 15. Histogram of the elevation differences between the WorldView-2 stereo satellite elevations for the 14.5km by 12km area and the 1,805 elevation checkpoints with slopes between 20% and 100% grade. RMSE 23cm, LE90 34cm.

Cautionary Statement:

This is an accuracy assessment for elevation mapping from a single stereo pair of WorldView-2 satellite photos. While in our experience these results are typical for most WorldView-2 stereo photos, these results may not apply to any specific pair of WorldView-2 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

NDEP Guidelines for Digital Elevation Data.
http://www.ndep.gov/NDEP_Elevation_Guidelines_Ver1_10May2004.pdf