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PhotoSat Kompsat-3A stereo satellite surveying accuracy study, Garlock Fault, California, 14 GCP, RMSE 21cm

- **144 km² surveyed using fourteen ground reference survey points**
- **This Kompsat-3A satellite elevation survey is accurate to 21cm RMSE, determined by comparison to 6,294 elevation checkpoints from a highly accurate LiDAR survey**
- **July, 2016 Kompsat-3A stereo satellite photos processed by PhotoSat in August, 2016**

Gerry Mitchell, P. Geo, Geophysicist, President PhotoSat
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A 1m grid of elevation values, covering an area of 144 square kilometres, was produced over a PhotoSat test area in California. The elevation grid was made using geophysical processing of 40cm ground resolution stereo satellite photos taken by the Kompsat-3A satellite. The stereo satellite elevation processing was referenced to fourteen ground survey points. The elevation surveying accuracy was determined by direct comparison to 6,294 elevation checkpoints extracted from a highly accurate LiDAR survey.

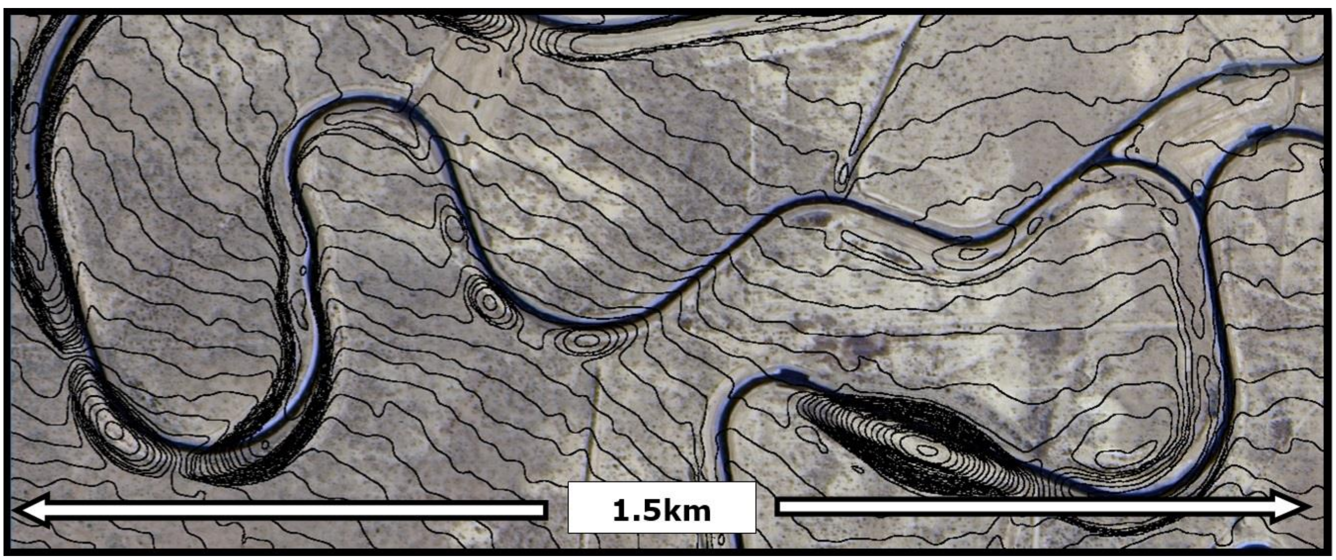

Figure 1. Kompsat-3A colour image with 50cm contours from the PhotoSat Kompsat-3A survey of the California test area.

The Garlock Fault was surveyed with LiDAR in April, 2008 by [OpenTopography](). The location of the LiDAR survey and the area of this Kompsat 3A stereo satellite survey accuracy study is shown in Figure 2. 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 Kompsat-3A stereo satellite photos, acquired November 28, 2014, is shown by the circle.

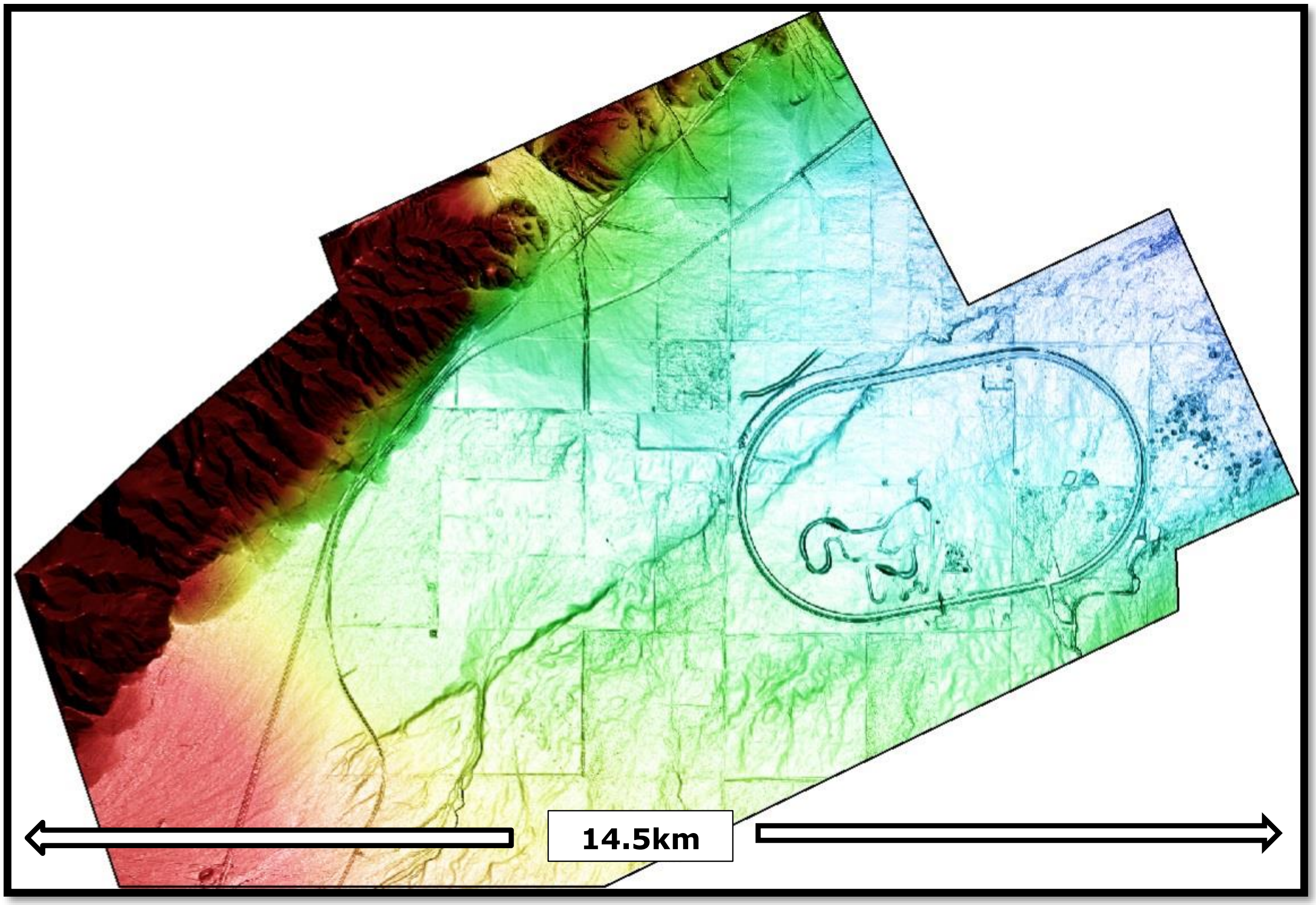

Figure 3. An elevation image showing the portion of the OpenTopography.org LiDAR survey used in this accuracy study. The dimensions of the area are 14.5km east–west by 9.9km north–south. Lower elevations are blue and higher elevations are red. The oval is the Honda California Test Track.

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 4.

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.

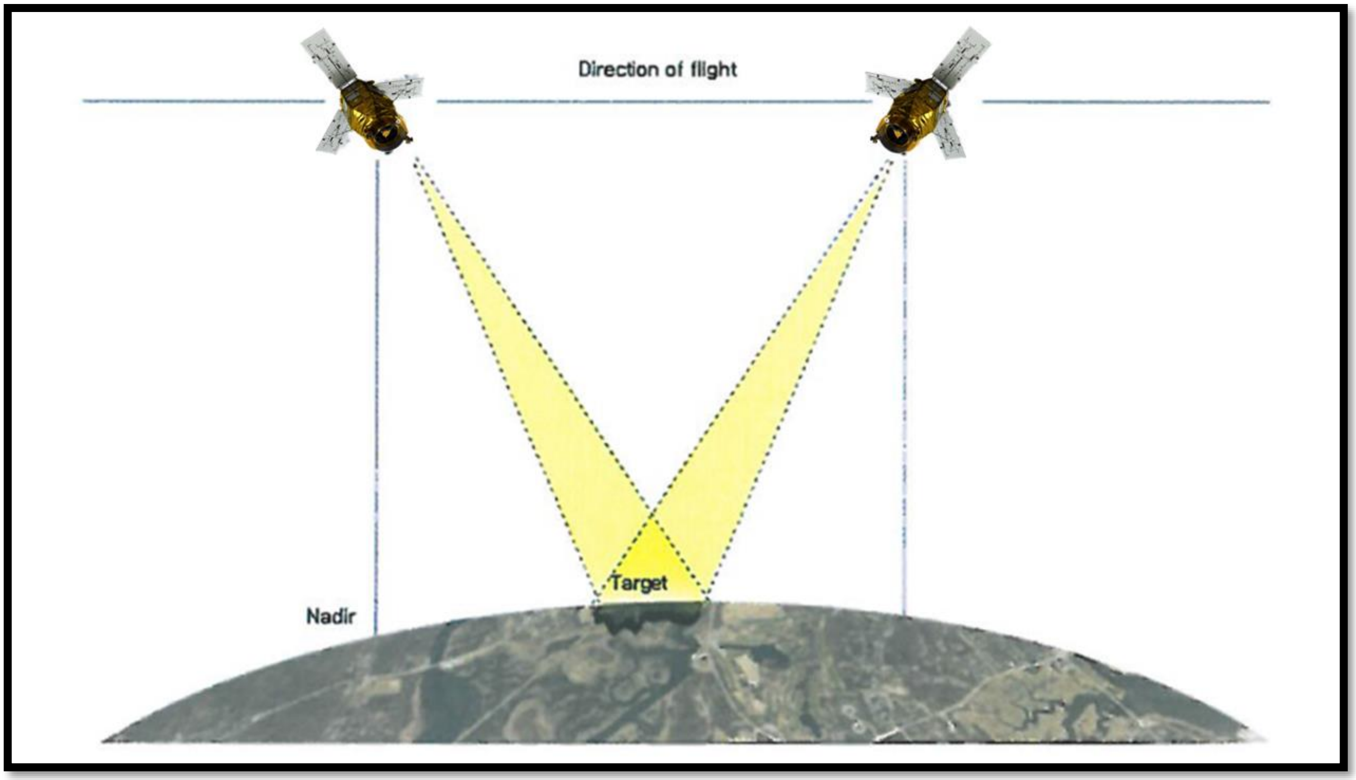

Figure 4. Illustration showing the process of taking satellite stereo photos. The satellite points forward to take the first photo. About one minute later, and 300km further along its orbital track, the satellite rotates to take the second photo looking backwards along the track. Hundreds of km^2 can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

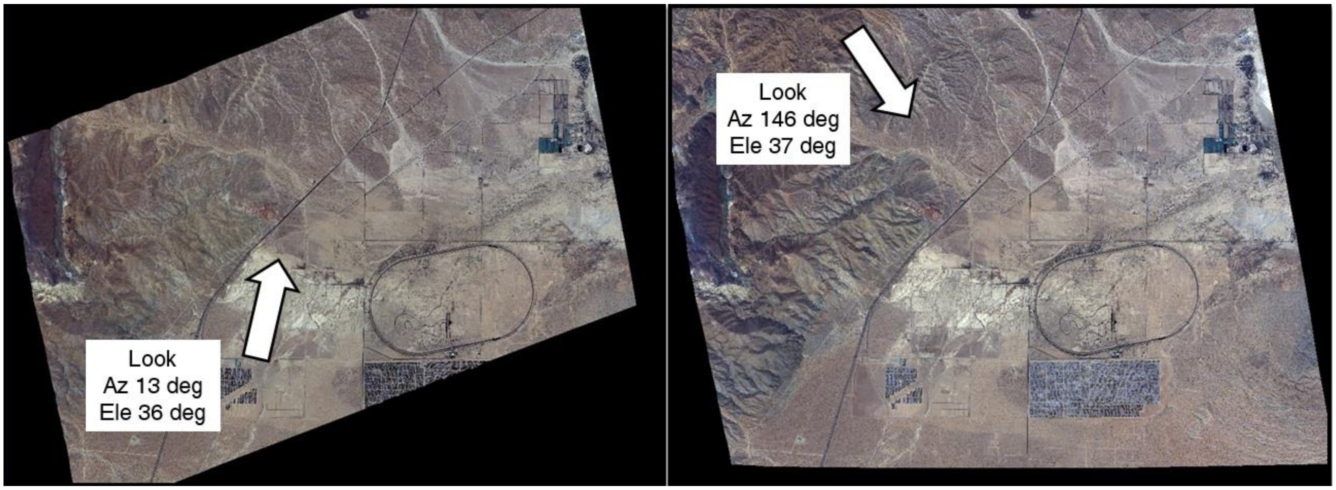

Figure 5. Kompsat-3A satellite photos of PhotoSat's California test area taken on July 29, 2016 at approximately 2:08 PM local time. The photo on the left was taken looking at an azimuth of 13 deg and angle from vertical of 36 deg. The photo on the right was taken looking at an azimuth of 146 deg and angle from vertical of 37 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 66 deg, a bisector azimuth of 82 deg and bisector angle of 17 deg from vertical.

California satellite photos:

The pair of stereo Kompsat-3A satellite photos over the California test area are shown in Figure 5. 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 66 deg is optimum for surveying elevations in level terrain.

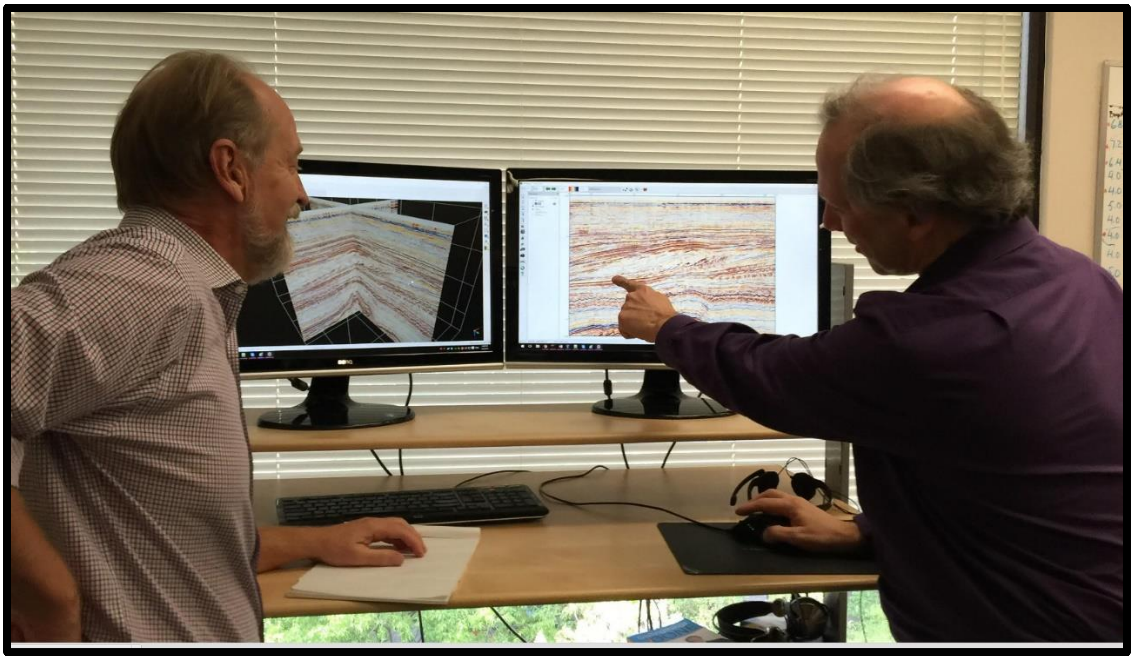

Figure 6. Gerry Mitchell, left, and Michael Ehling with an Oil and Gas seismic processing workstation. This technology is the basis for the PhotoSat geophysical stereo satellite processing system named the PhotoSat Process Manager.

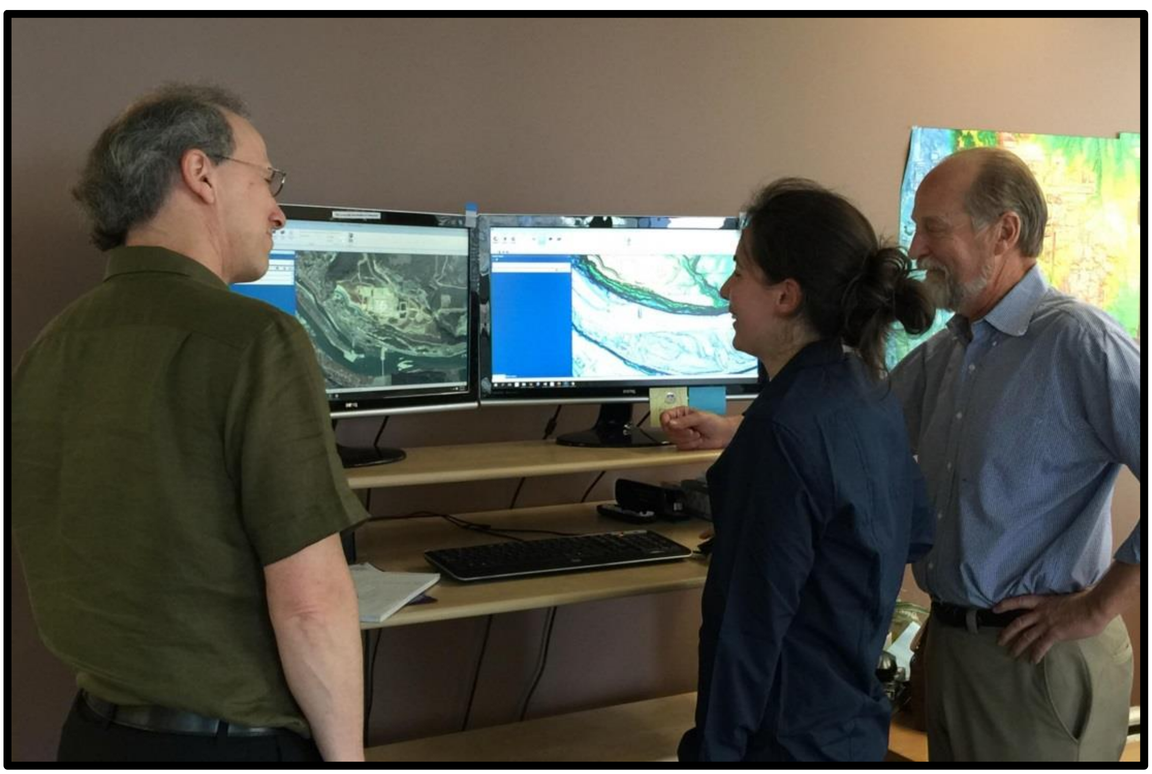

Figure 7. Michael, Gerry and Jayda Akatsuka with the PhotoSat Process Manager.

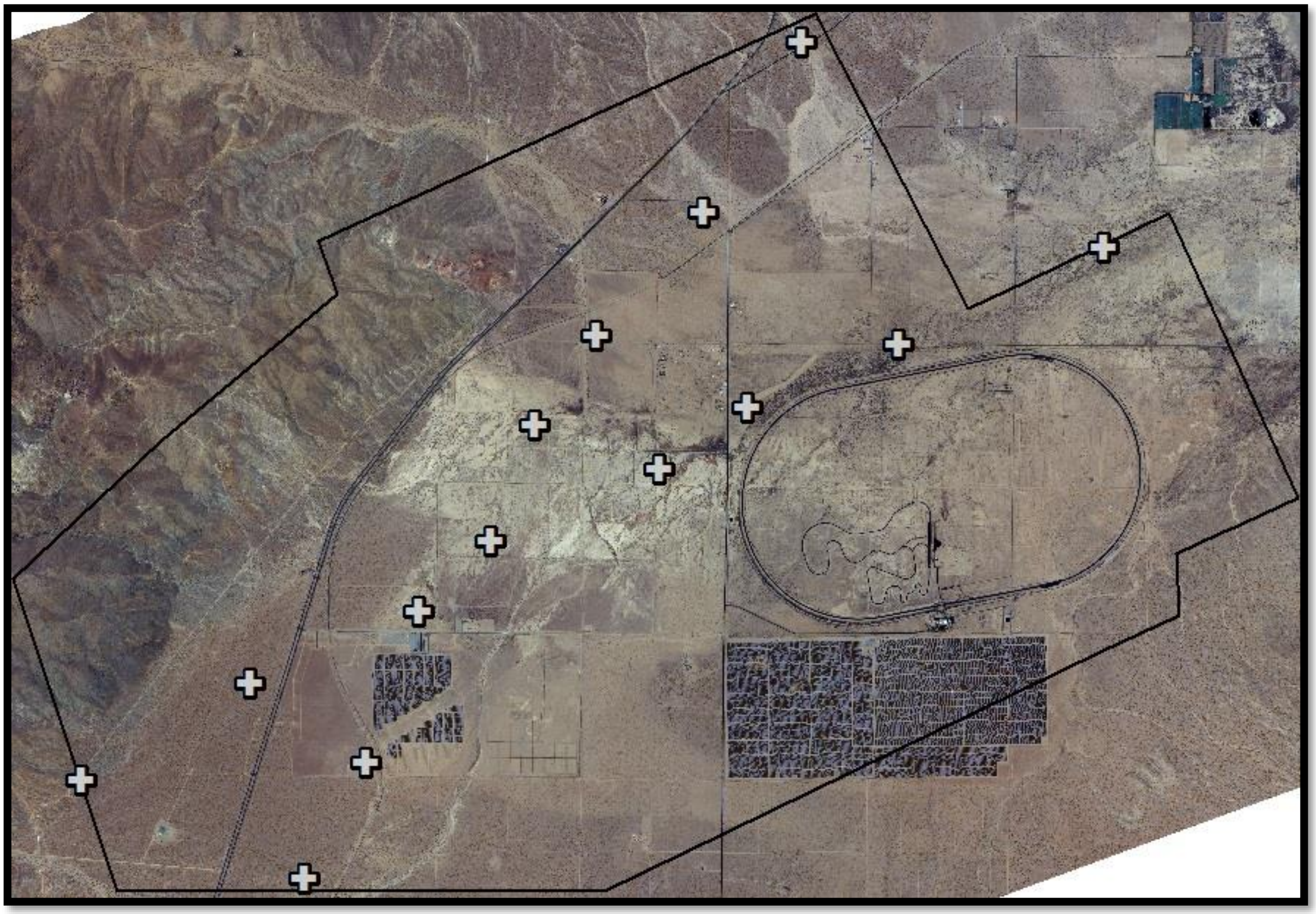

Figure 8. Kompsat-3A 50cm resolution orthophoto, created from the Kompsat-3A stereo photos, for the area of the LiDAR survey used in this study. The 7.5 mile oval track is the Honda California Test Track. The 14 ground reference points are shown as a white crosses. The ground reference points were extracted from the LiDAR survey data.

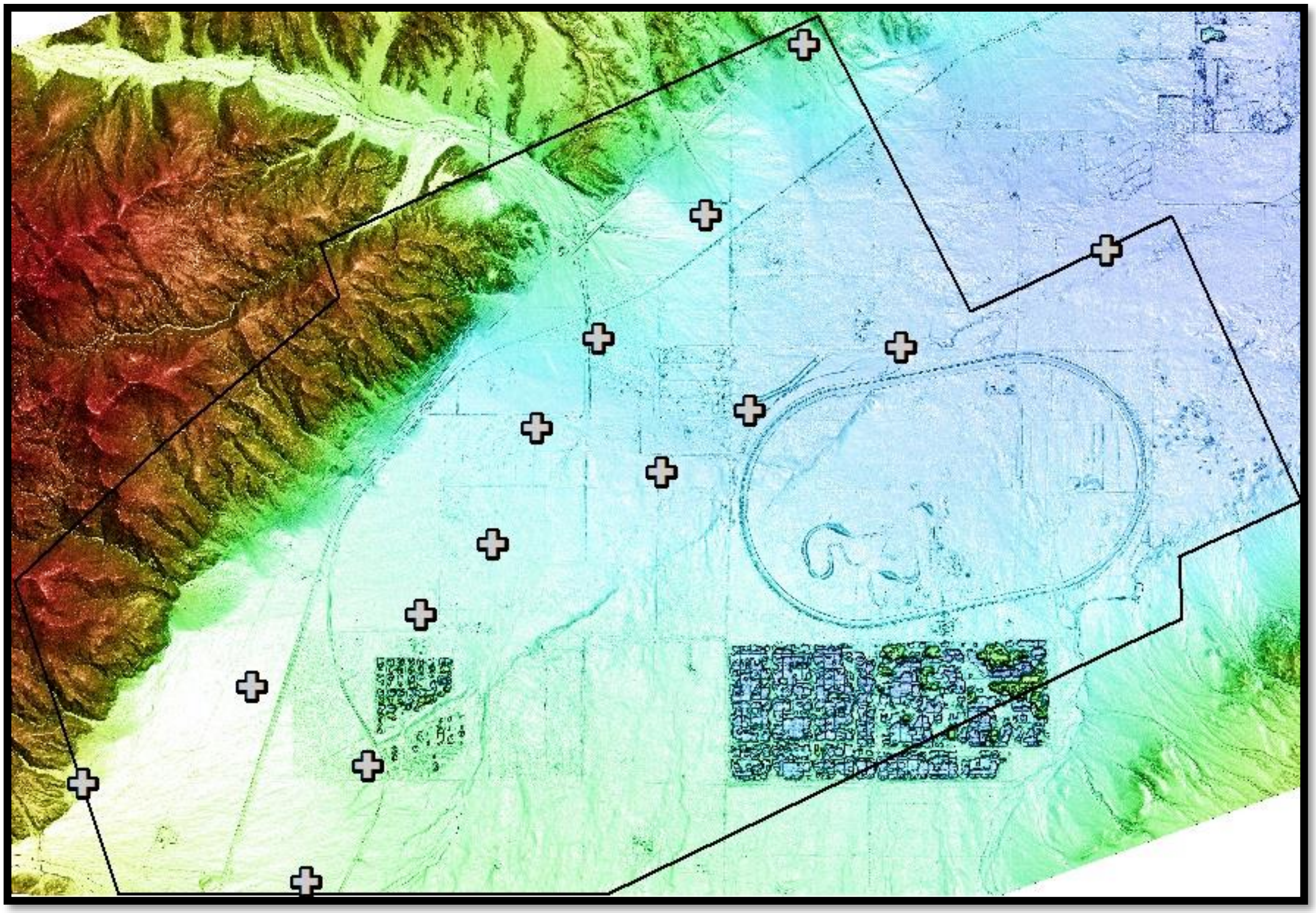

Figure 9. Stereo Kompsat-3A elevation image covering the area of the LiDAR image in Figure 3. This elevation grid has an elevation point every meter. At this scale, the LiDAR and Kompsat-3A images are identical. Low elevations are blue and high elevations are red.

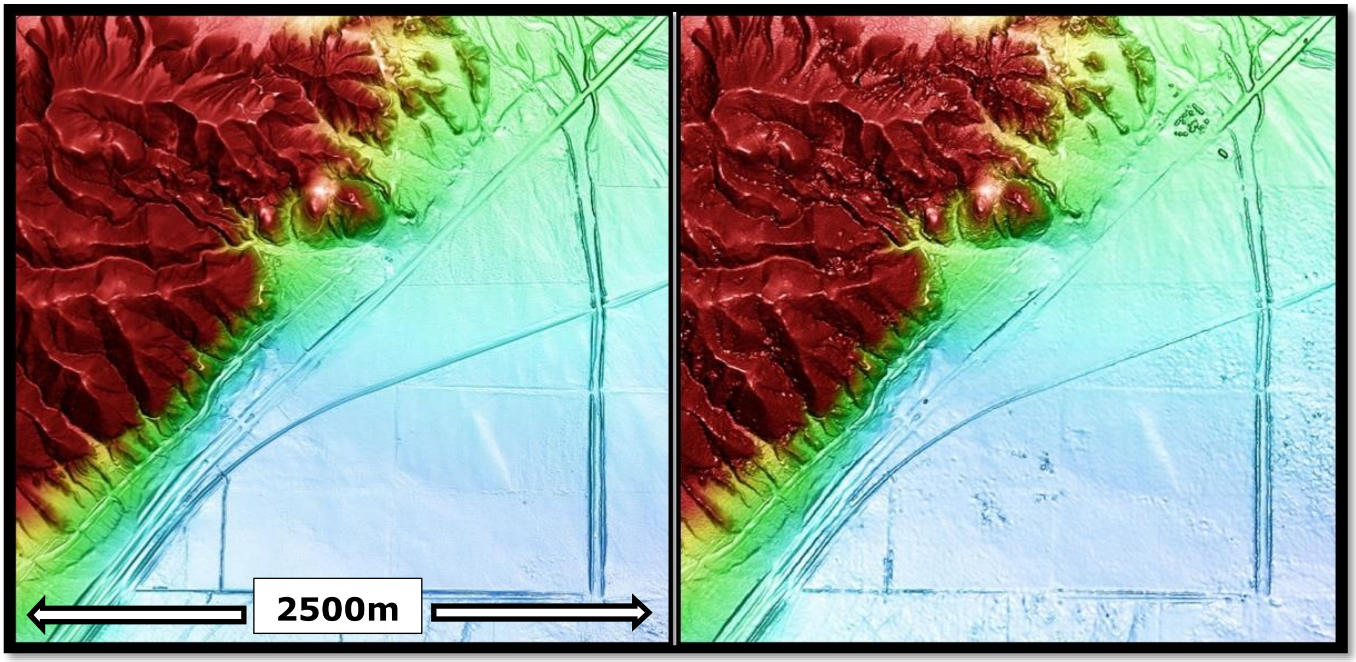

Figure 10. Comparison of the elevation grids between the LiDAR on the left and the stereo Kompsat-3A on the right. This is for a 2,500m wide area. Minor differences between the elevation grids are visible at this scale.

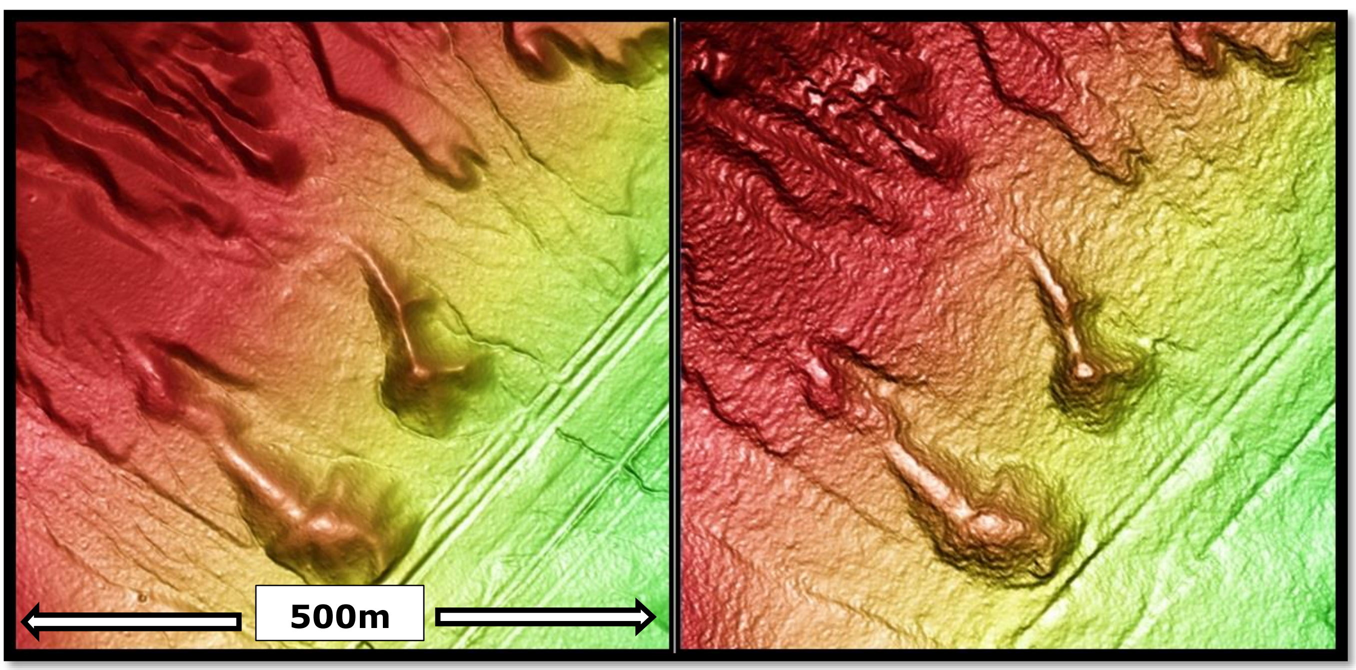

Figure 11. Comparison of the elevation grids between the LiDAR on the left and the stereo Kompsat-3A on the right. This is for a 500m wide area. More topographic detail is visible on the LiDAR at this scale.

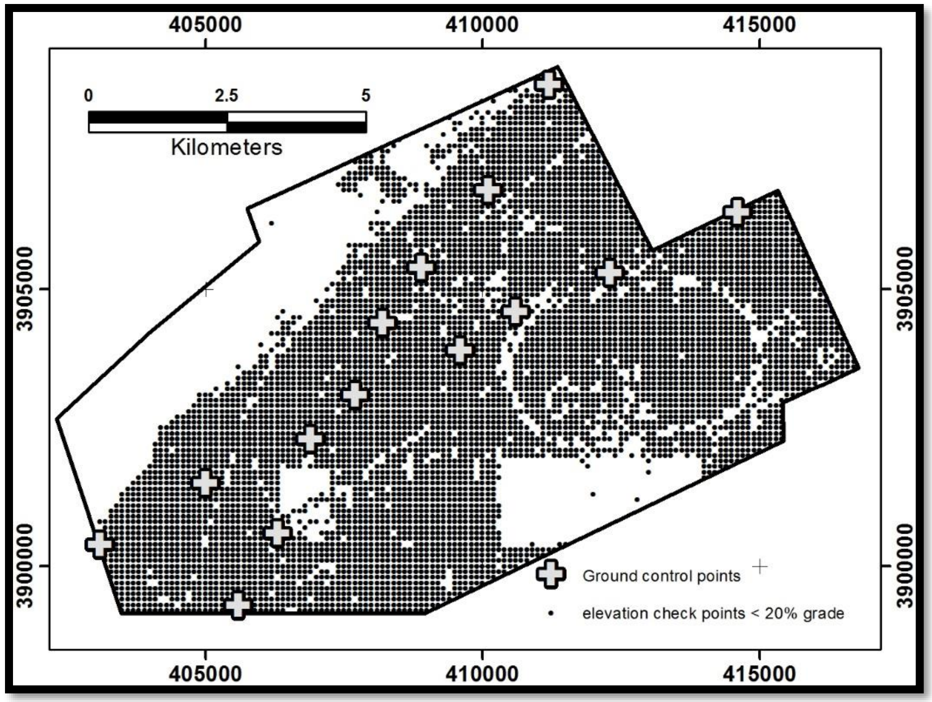

Figure 12. Elevation checkpoints for areas with slopes of less than 20% grade.

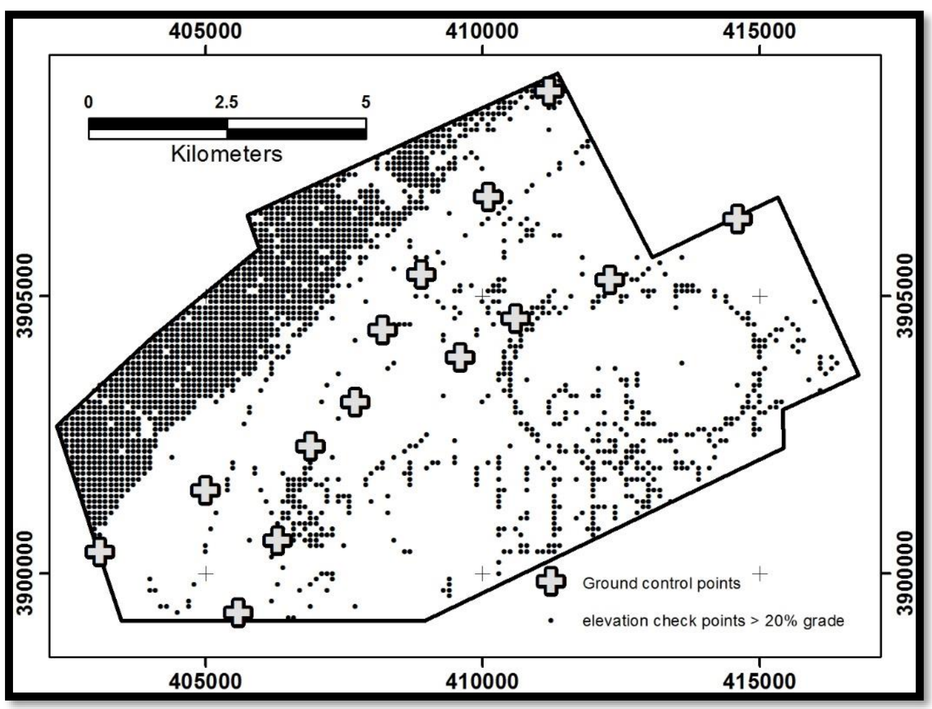

Figure 13. Elevation checkpoints for areas with slopes of greater than 20% grade.

California elevation grid:

PhotoSat produced a 1m grid of elevations over the entire project area. We processed the stereo Kompsat-3A photos with our geophysical stereo satellite processing system in August, 2016. An image of the 1m elevation grid is shown in Figure 9.

Ground reference points:

With this accuracy study we are demonstrating that we can produce highly accurate Kompsat-3A surveys with only fourteen ground reference points. Having fourteen ground reference survey points for a 144 km^2 satellite surveying project is typical in mining exploration projects.

The location of the ground reference points are shown in Figure 8.

Accuracy evaluation checkpoints:

The accuracy of the PhotoSat 1m survey grid was evaluated with 6,294 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 6,294 elevation checkpoints with slopes less than 20% grade have an RMSE of 21cm as shown in Figure 14.

The 1,959 points on slopes over 20% grade have an RMSE of 64cm as shown in Figure 15.

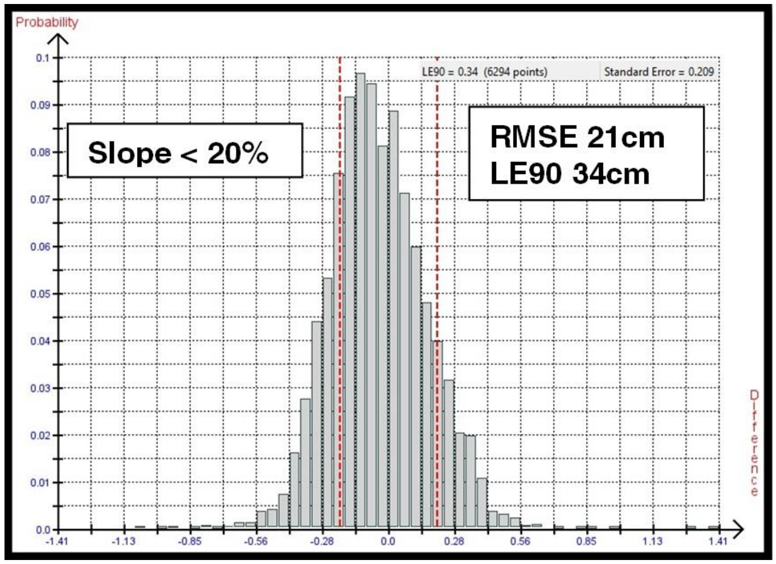

Figure 14. Histogram of the elevation differences between the Kompsat-3A stereo satellite elevations for the 14.5km by 9.9km area and the 6,294 elevation checkpoints with slopes less than 20% grade. The *Guidelines for Digital Elevation Data* of the US National Digital Elevation Program (NDEP) recommends that elevation checkpoints should be chosen in areas with slopes less than 20% grade. RMSE 21cm, LE90 34cm.

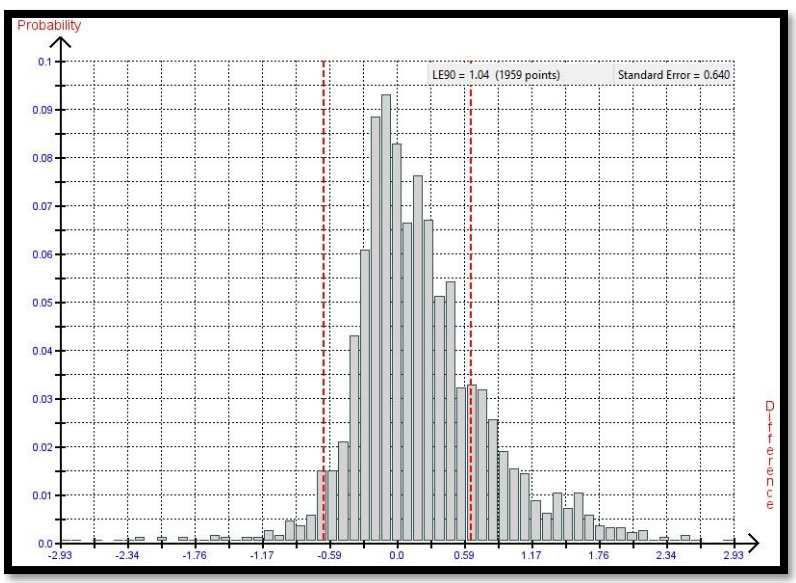

Figure 15. Histogram of the elevation differences between the Kompsat-3A stereo satellite elevations for the 14.5km by 9.9km area and the 1,959 elevation checkpoints with slopes between 20% and 100% grade. RMSE 64cm, LE90 104cm.

Cautionary Statement:

This is an accuracy assessment for elevation mapping from a single stereo pair of Kompsat-3A satellite photos. These results may not apply to any specific pair of Kompsat-3A 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