PhotoSat
Leaders in Satellite Surveying
for Mining and Energy
www.photosat.ca

PhotoSat
1188 West Georgia Street, Suite 580
Vancouver, British Columbia, Canada, V6E 4A2
Tel: +1 (604) 681 9770

PhotoSat WorldView-1 stereo satellite surveying accuracy study, Asmara, Eritrea, 9 GCP, RMSE 23cm

- **420 km² surveyed using only nine ground reference survey points**
- **This WorldView-1 satellite elevation surveying accuracy is accurate to 23cm RMSE, determined by 2,721 survey checkpoints**
- **October 2008 WorldView-1 stereo satellite photos processed by PhotoSat in November 2016**

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

A 1m grid of elevation values covering an area of 420 square kilometres was produced over a PhotoSat test area in Eritrea. The elevation grid was made using geophysical processing of 50cm ground resolution stereo satellite photos taken by the DigitalGlobe WorldView-1 satellite. The stereo satellite elevation processing referenced nine ground survey points. The elevation surveying accuracy was measured with over 2,500 survey checkpoints.

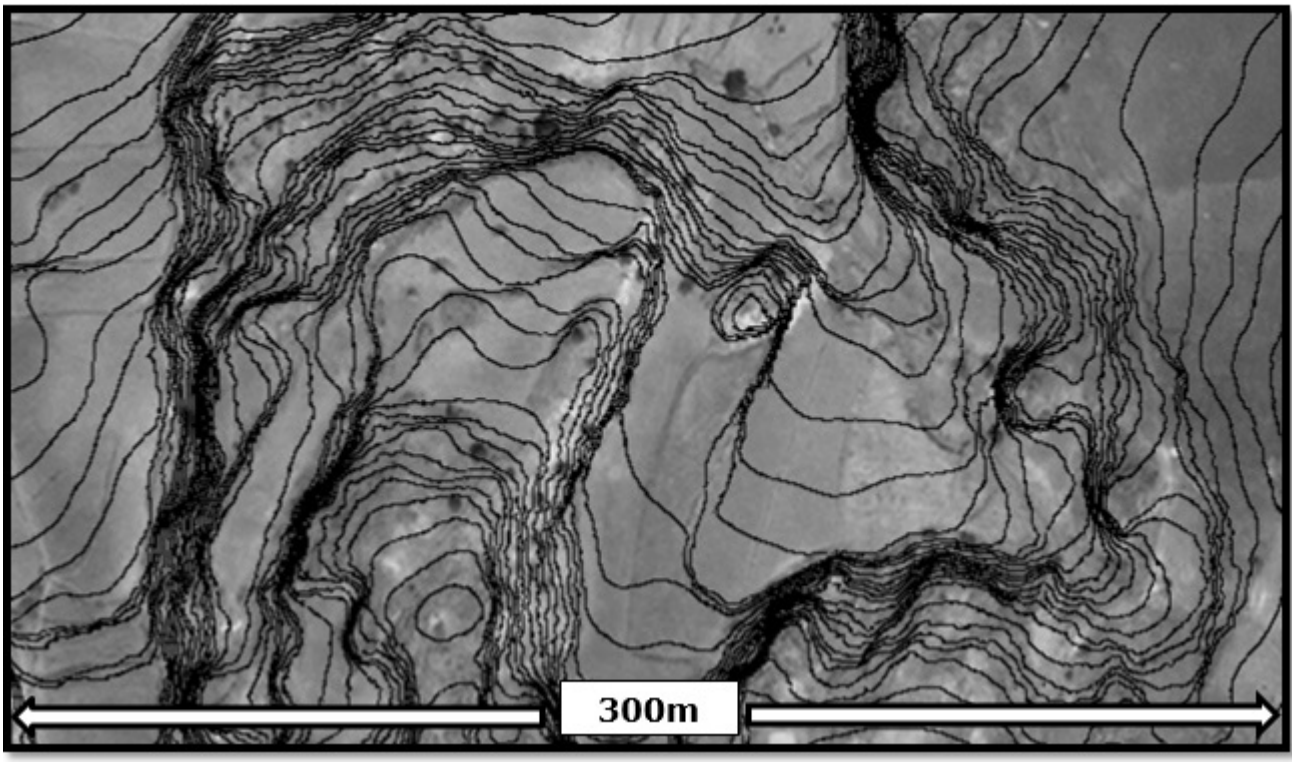

Figure 1. WorldView-1 panchromatic image with 50cm contours from the PhotoSat
Stereo satellite photos:

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.

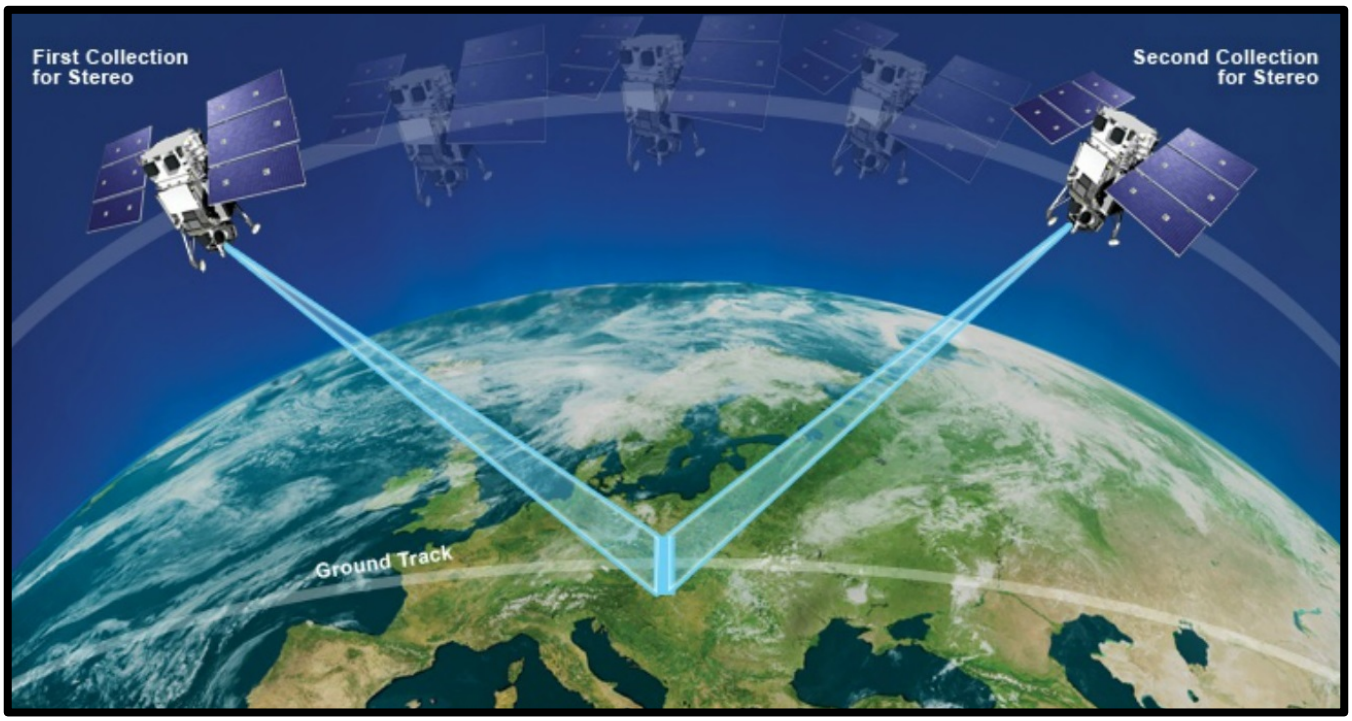

Figure 2. Illustration showing the process of taking satellite stereo photos. The satellite points forward to take the first photo. About one minute later, and 300 km further along its orbital track, the satellite rotates to take the second photo looking backwards along the track. Hundreds of km^2 can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

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.

Eritrea satellite photos:

The pair of stereo WorldView-1 satellite photos over the Eritrea test area are shown in Figure 3. The photos were taken on October 23, 2008 at approximately 11:00 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 37 deg is optimum for surveying elevations in level to moderate terrain.

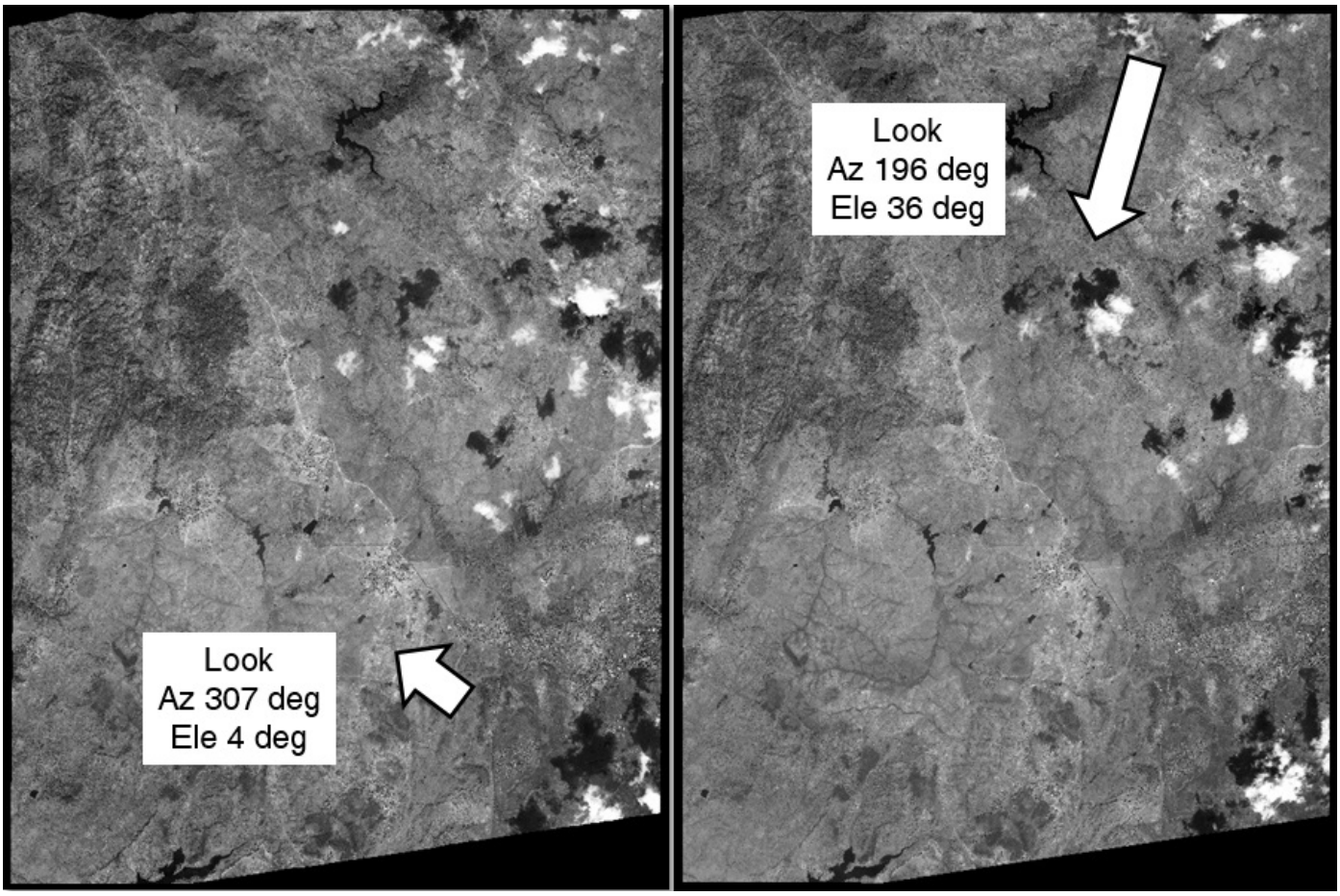

Figure 3. WorldView-1 satellite photos of PhotoSat's Eritrea test area taken on October 23, 2008 at approximately 11:00 AM local time. The photo on the left was taken looking at an azimuth of 307 deg and angle from vertical of 4 deg. The photo on the right was taken looking at an azimuth of 196 deg and angle from vertical of 36 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 37 deg, a bisector azimuth of 203 deg and bisector angle of 17 deg from vertical.

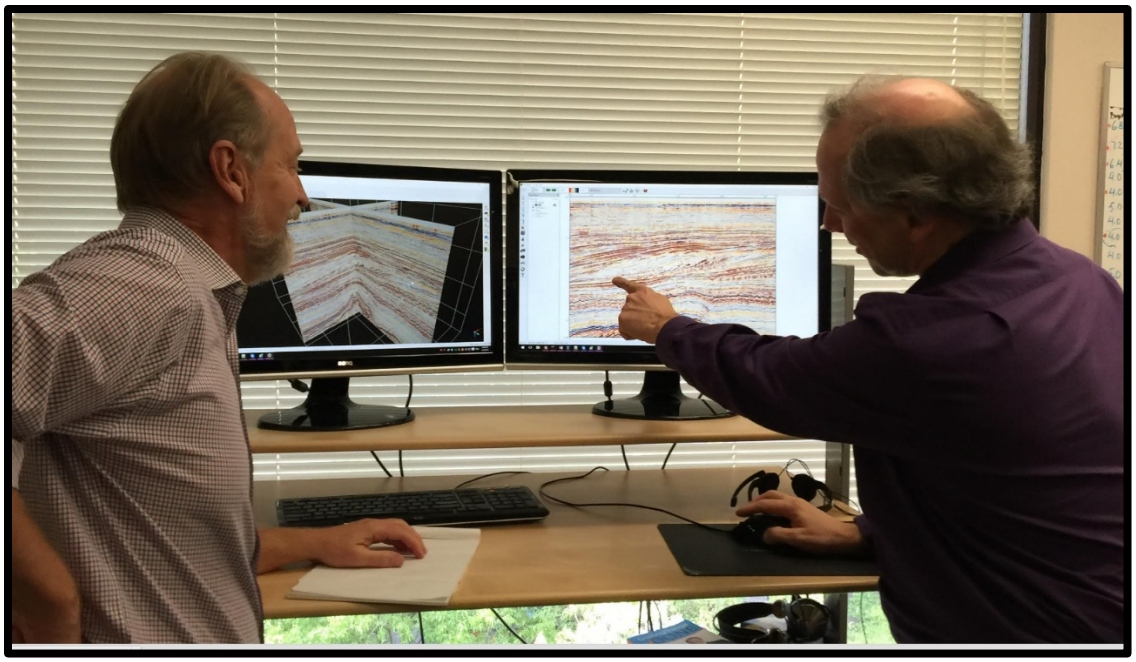

Figure 4. Gerry Mitchell, left and Michael Ehling with an Oil and Gas seismic processing workstation. This technology is the basis for the PhotoSat geophysical stereo satellite processing system named the PhotoSat Process Manager.

Figure 5. Michael, Gerry and Jayda Akatsuka with the PhotoSat Process Manager.

Eritrea 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 November 2016. An image of the 1m elevation grid is shown in Figure 7.

Ground reference points:

With this accuracy study we are demonstrating that we can produce highly accurate WorldView-1 surveys with a reasonable distribution of ground reference survey points. Having as little as nine ground reference points for a 420 km^2 satellite surveying project is not uncommon in mining exploration projects.

The locations of the ground reference points are shown in Figure 6. The survey crew and system are shown in Figure 9.

Global shift of stereo satellite survey to match ground reference:

The WorldView ortho photo and elevation grid needed a constant shift of -5.0m E, 75cm N and -7.06m in elevation to match the ground surveying. This relatively large shift may be related to the fact that this WorldView-1 stereo pair was collected less than two months after the satellite launch. 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 2,721 ground survey check points. These points were originally surveyed for a large mining exploration gravity survey conducted between 2004 and 2008 by MWH Geophysics. The distribution of the elevation checkpoints is shown in Figure 8.

The elevation check points were surveyed to an accuracy of 2 cm using Real Time Kinematic GPS survey equipment. One of the MWH Geophysics survey teams and their equipment are shown in Figure 9. The accuracy check points were extracted from a 250m by 250m regional grid of survey points. This can be seen in Figure 8.

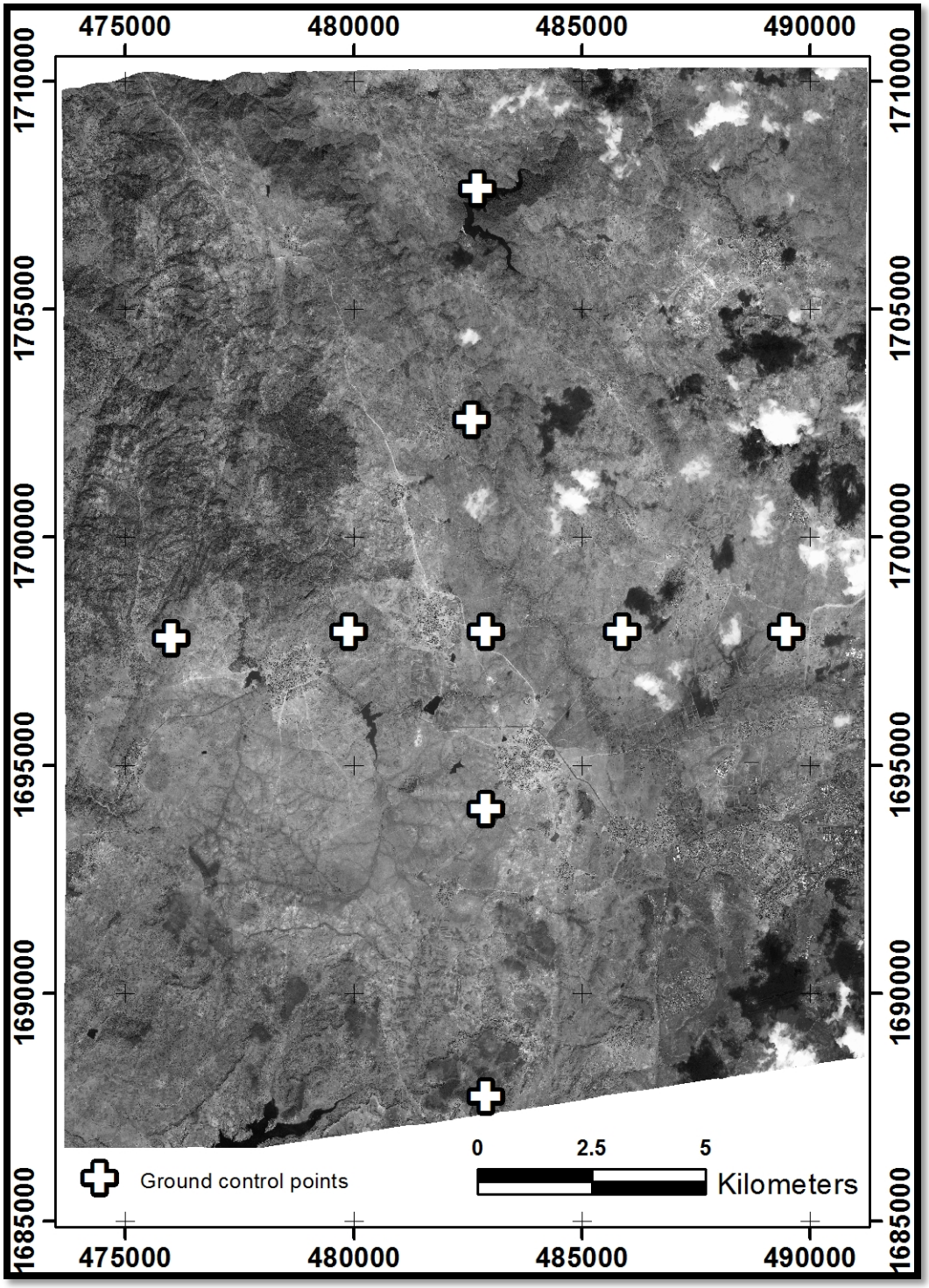

Figure 6. WorldView-1 50cm stereo satellite photo. Asmara, Eritrea.

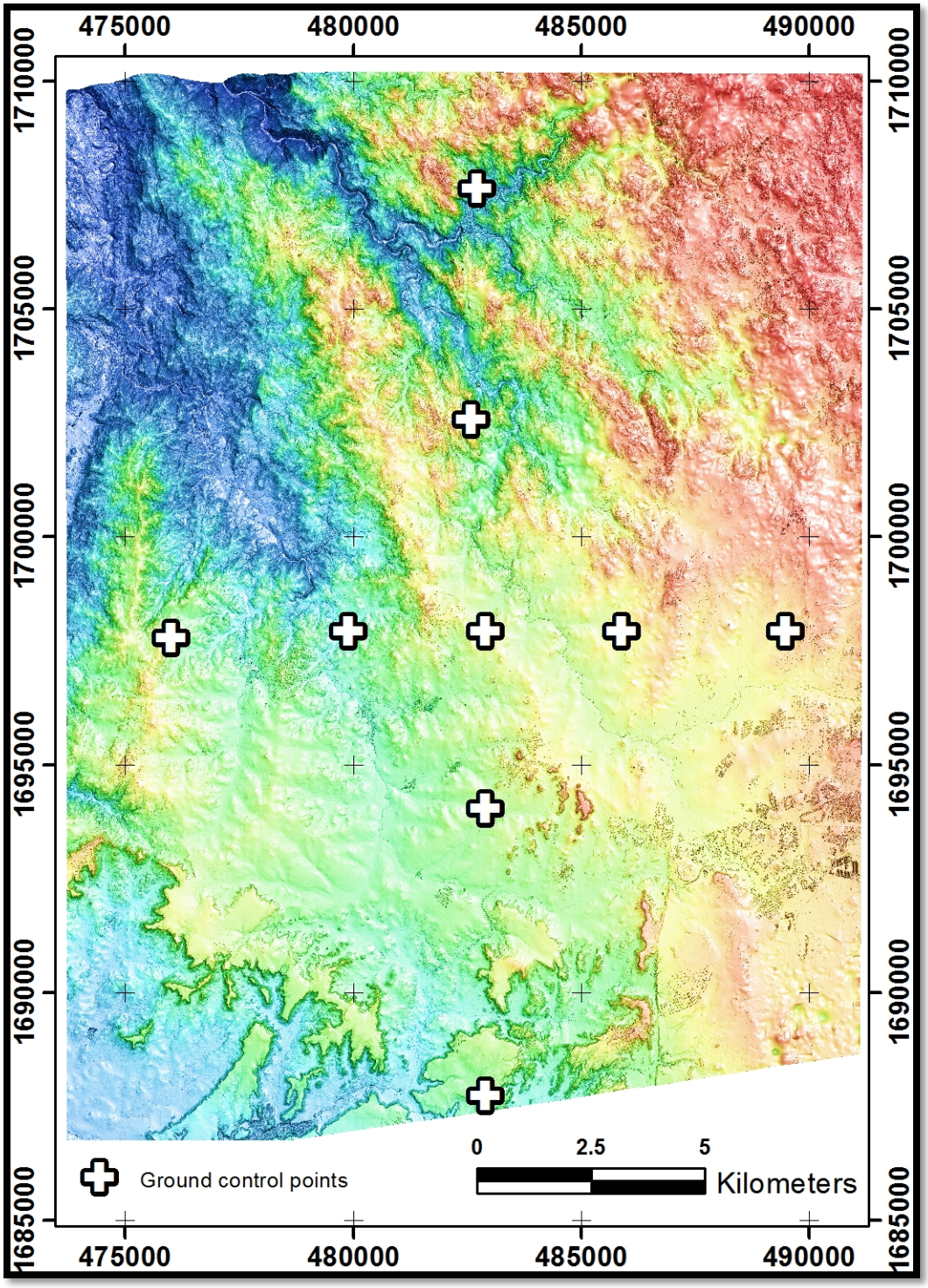

Figure 7. Stereo WorldView-1 elevation image created from the 1m PhotoSat Asmara, Eritrea satellite survey grid. The figure shows the locations of the nine ground control points.

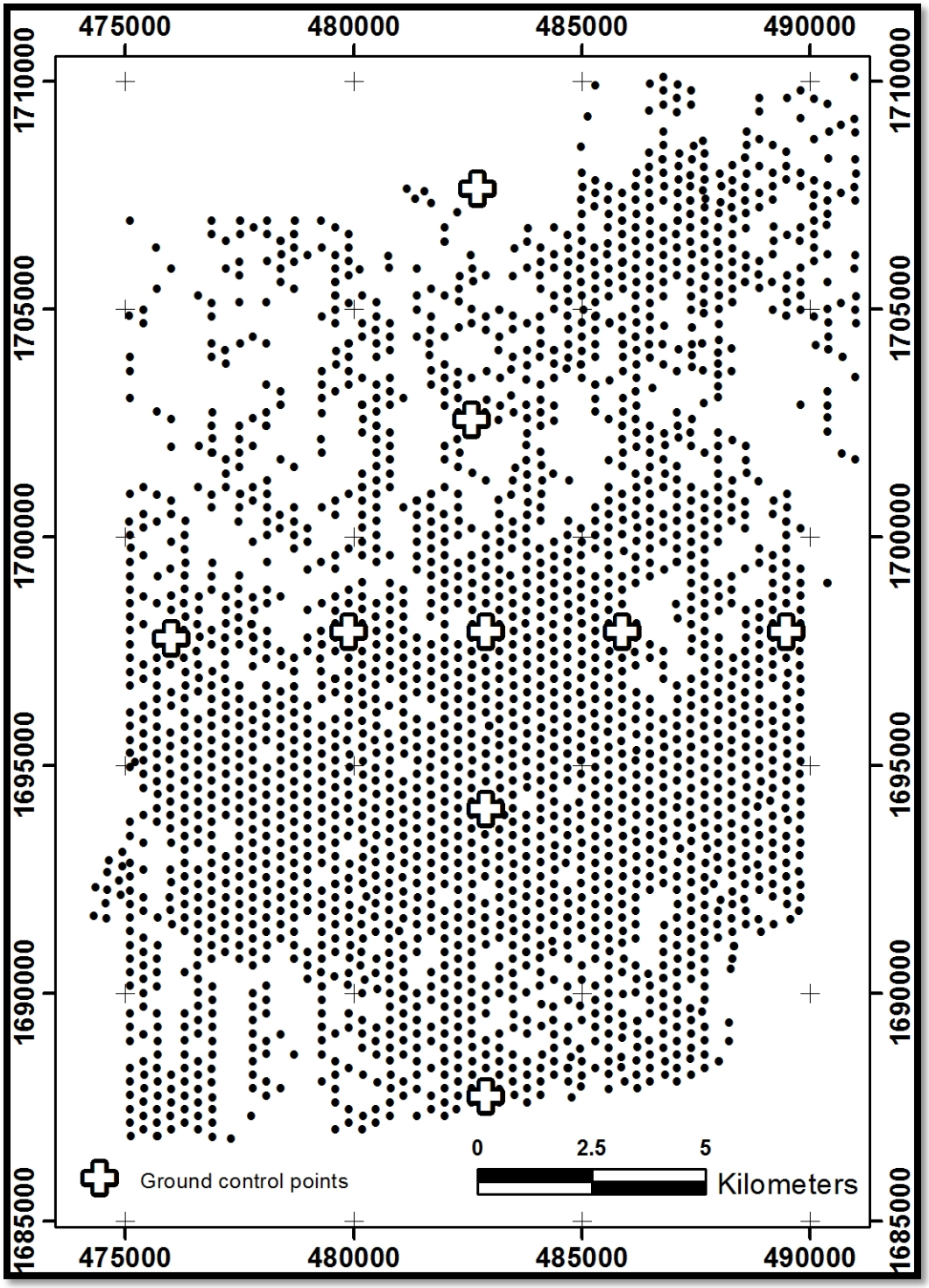

Figure 8. Area of the 23.7km by 17.7km Eritrea Stereo WorldView-1 1m elevation grid showing the nine ground control points and the 2,721 gravity survey stations used as elevation checkpoints to determine the accuracy of the stereo satellite survey.

Figure 9. Asmara Project, Eritrea. MWH Geo-Surveys differential GPS survey crew and equipment. The Magellan RTK base with a ProMark™ 500 GPS rover are shown in this photo.

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 2,721 elevation checkpoints with slopes less than 20% grade have an RMSE of 23cm as shown in Figure 10.

A histogram of the elevation differences between the PhotoSat WorldView survey grid and all 3,339 ground survey check points is shown in Figure 11. The RMSE using all of the points is 25cm.

The points on slopes over 20% grade have an RMSE of 32cm as shown in Figure 12.

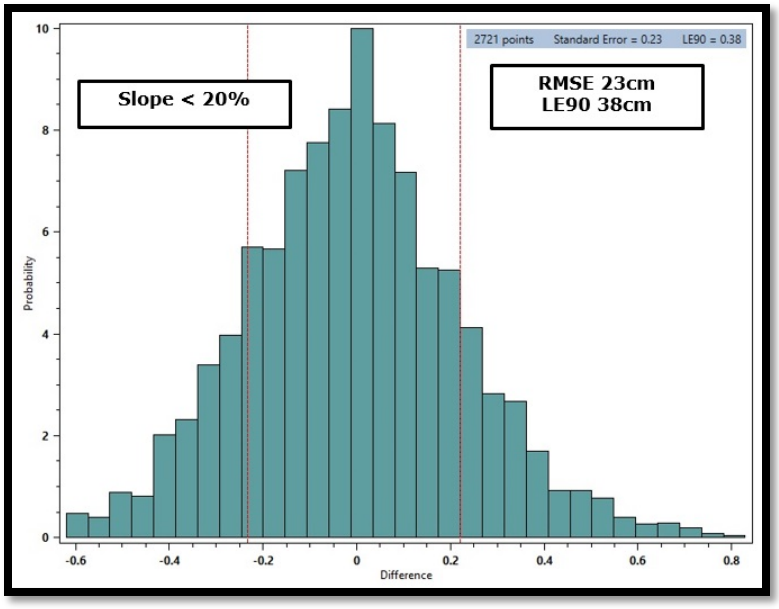

Figure 10. Histogram of the elevation differences between the WorldView-1 stereo satellite elevations for the 23.7km by 17.7km area and the 2,721 elevation checkpoints with slopes less than 20% grade. The *Guidelines for Digital Elevation Data* of the US National Digital Elevation Program (NDEP) recommends that elevation checkpoints should be chosen in areas with slopes less than 20% grade. RMSE 23cm, LE90 38cm.

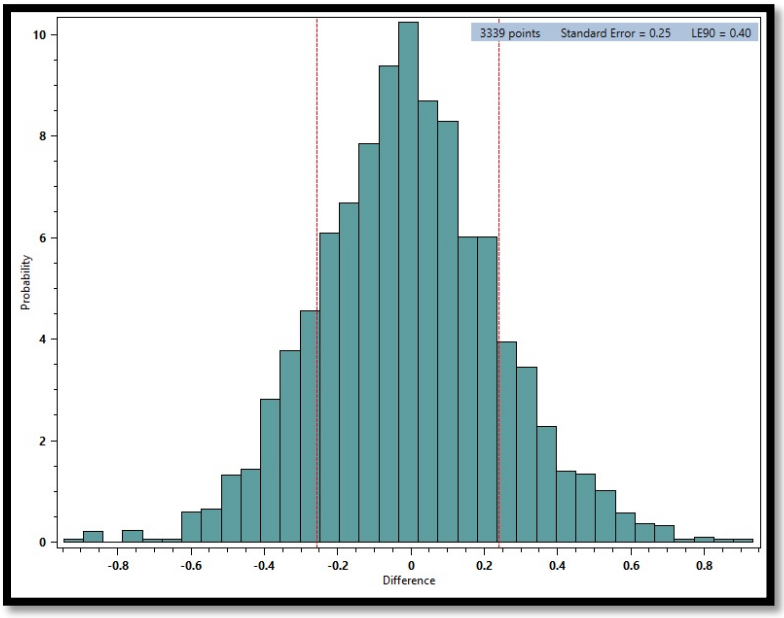

Figure 11. Histogram of the elevation differences between the WorldView-1 stereo satellite elevations for the 23.7km by 17.7km area and all 3,339 elevation checkpoints. RMSE 25cm, LE90 40cm.

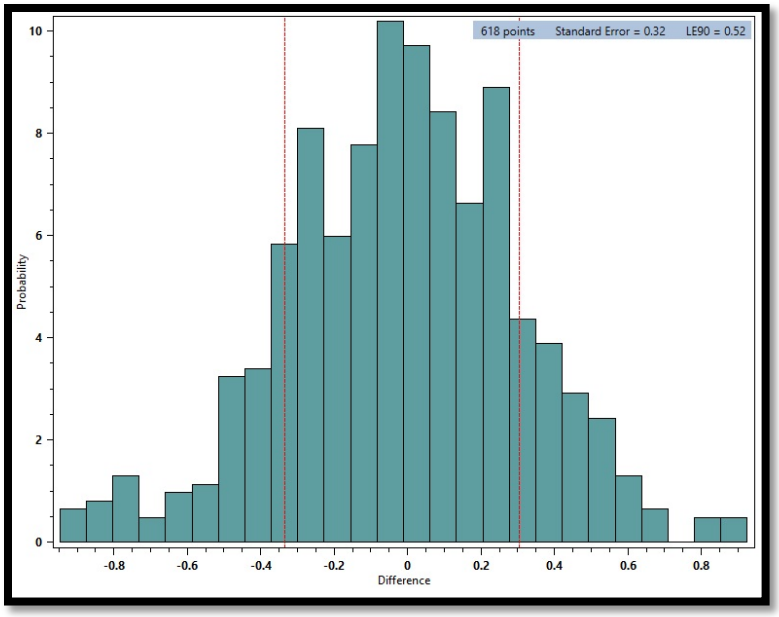

Figure 12. Histogram of the elevation differences between the WorldView-1 stereo satellite elevations for the 23.7km by 17.7km area and the 618 elevation checkpoints with slopes between 20% and 100% grade. RMSE 32cm, LE90 52cm.

Comparison between elevation check points and 50cm PhotoSat contours:

The very close agreement between the satellite survey elevations and the ground survey check points can be seen in Figure 13. Labeled 50cm contours are shown with the posted elevations of the ground survey points for a small area. This figure is typical of the agreement between the PhotoSat survey and the ground survey over the entire survey area.

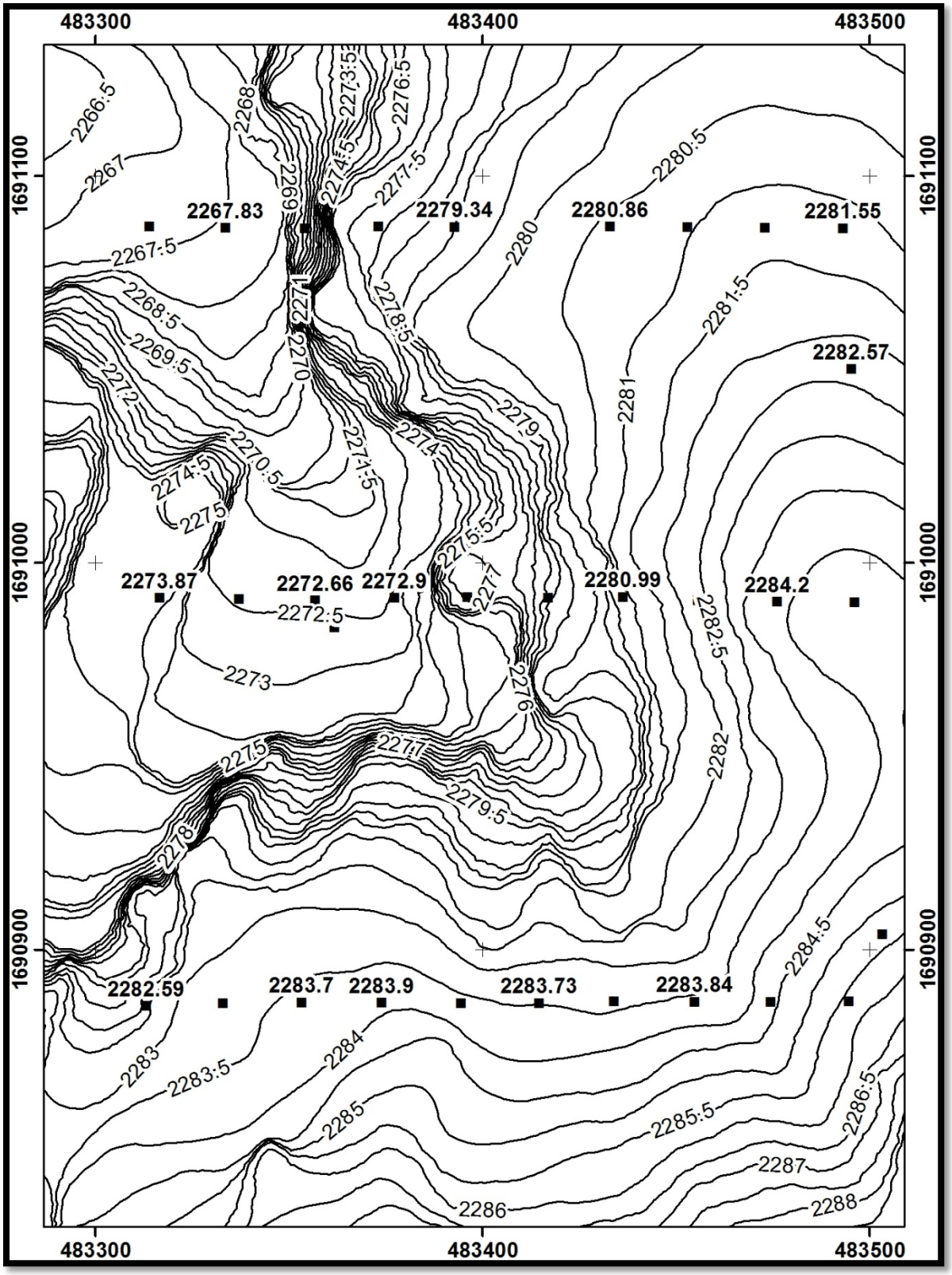

Figure 14. 50cm contours from the stereo WorldView-1 elevation survey comparing the contour elevations to some of the elevation checkpoints.

Qualifying Statement:

This is an accuracy assessment for elevation mapping from a single stereo pair of WorldView-1 satellite photos. In our experience these results are slightly less accurate than accuracy results for most WorldView-1 stereo photos. This may be related to the fact that this WorldView-1 stereo pair was collected less than two months after the satellite launch.

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