PhotoSat
Leaders in Satellite Surveying for Mining and Energy
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PhotoSat Kompsat-3A stereo satellite surveying accuracy study, Asmara, Eritrea, 11 GCP, RMSE 48cm

- **130 km² surveyed using eleven ground reference survey points**
- **This Kompsat-3A satellite elevation surveying accuracy is accurate to 48cm RMSE, determined by 1,406 survey checkpoints**
- **October 2016 Kompsat-3A stereo satellite photos processed by PhotoSat in November 2016**

Gerry Mitchell, P. Geo, Geophysicist, President PhotoSat
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A 1m grid of elevation values covering an area of 130 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 Kompsat-3A satellite. The stereo satellite elevation processing referenced eleven ground survey points. The elevation surveying accuracy was measured with over 1,000 survey checkpoints.

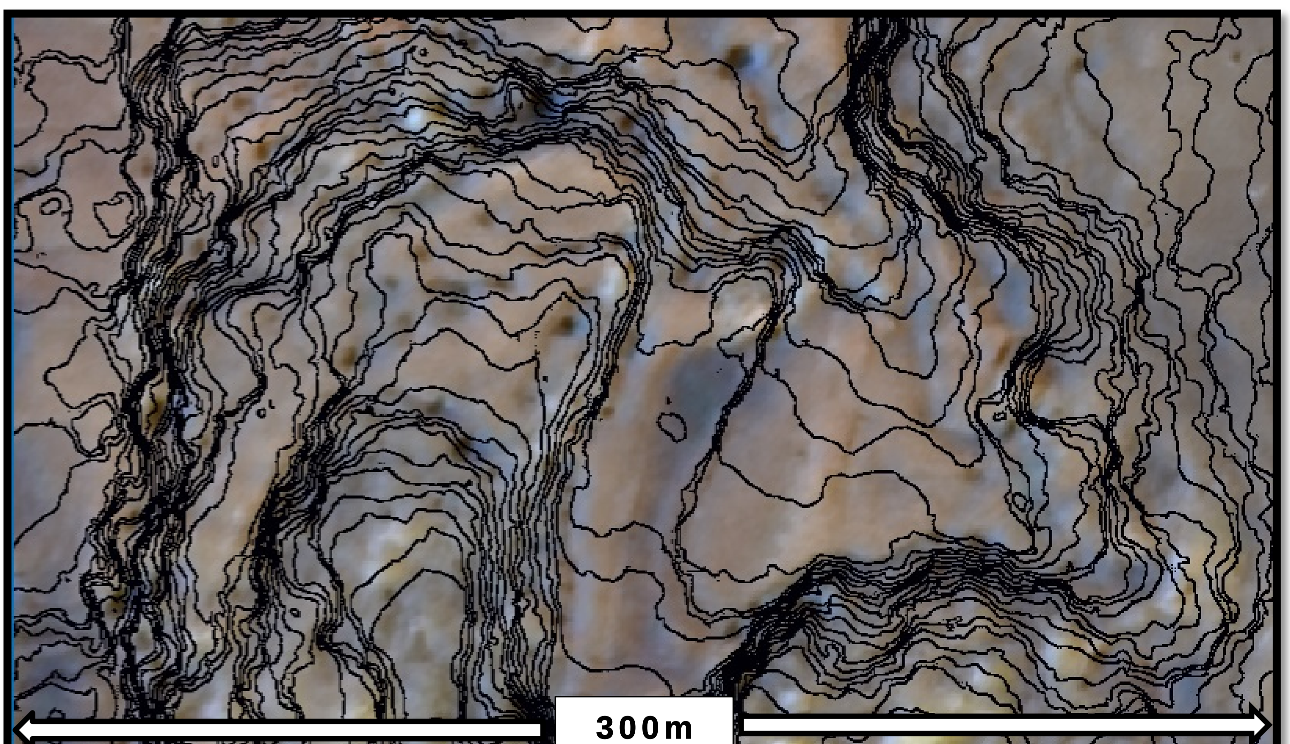

Figure 1. Kompsat-3A color image with 50cm contours from the PhotoSat kompsat-3A survey of the Eritrea test area.

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.

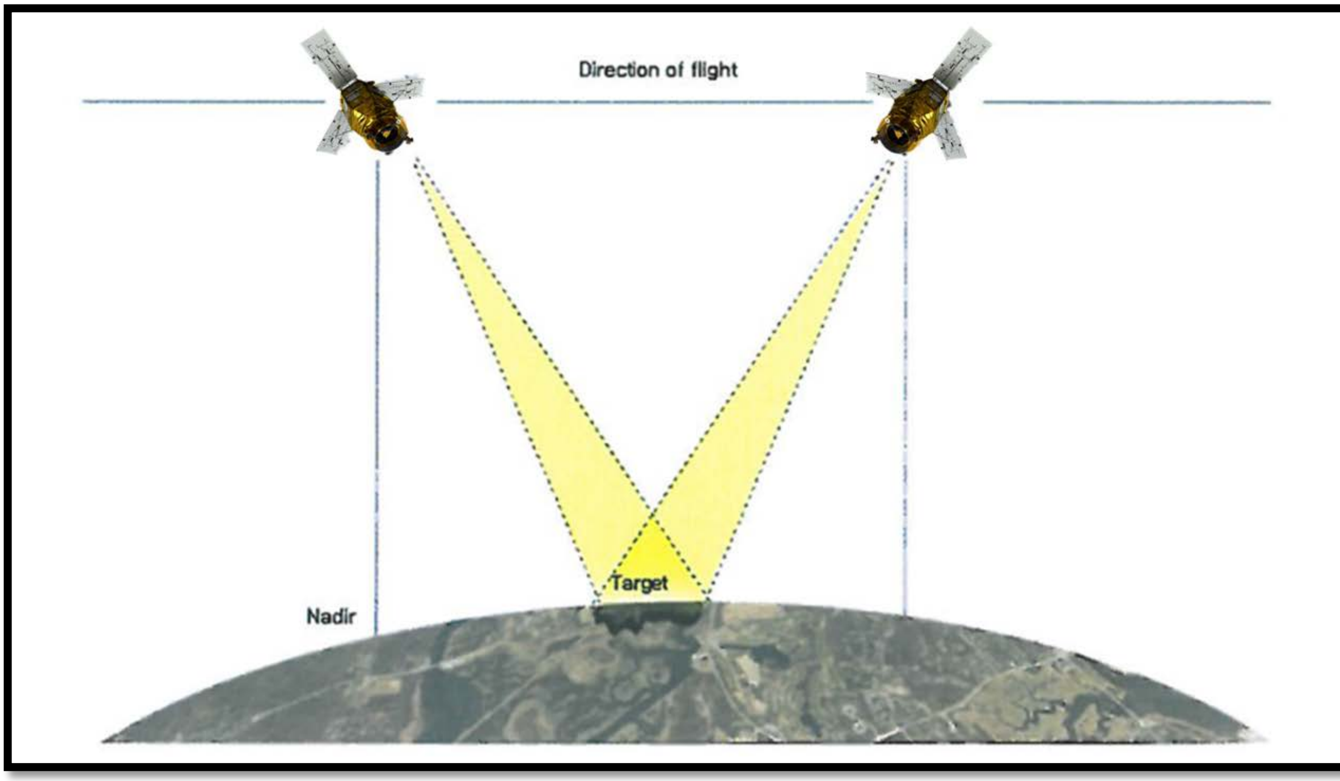

Figure 2. Illustration showing the process of taking satellite stereo photos. The satellite points forward to take the first photo. About one minute later, and 300 km further along its orbital track, the satellite rotates to take the second photo looking backwards along the track. Hundreds of km^2 can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

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 Kompsat-3A satellite photos over the Eritrea test area are shown in Figure 3. The photos were taken on October 31, 2016 at approximately 1:40 PM 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 66 deg is optimum for surveying elevations in level to moderate terrain.

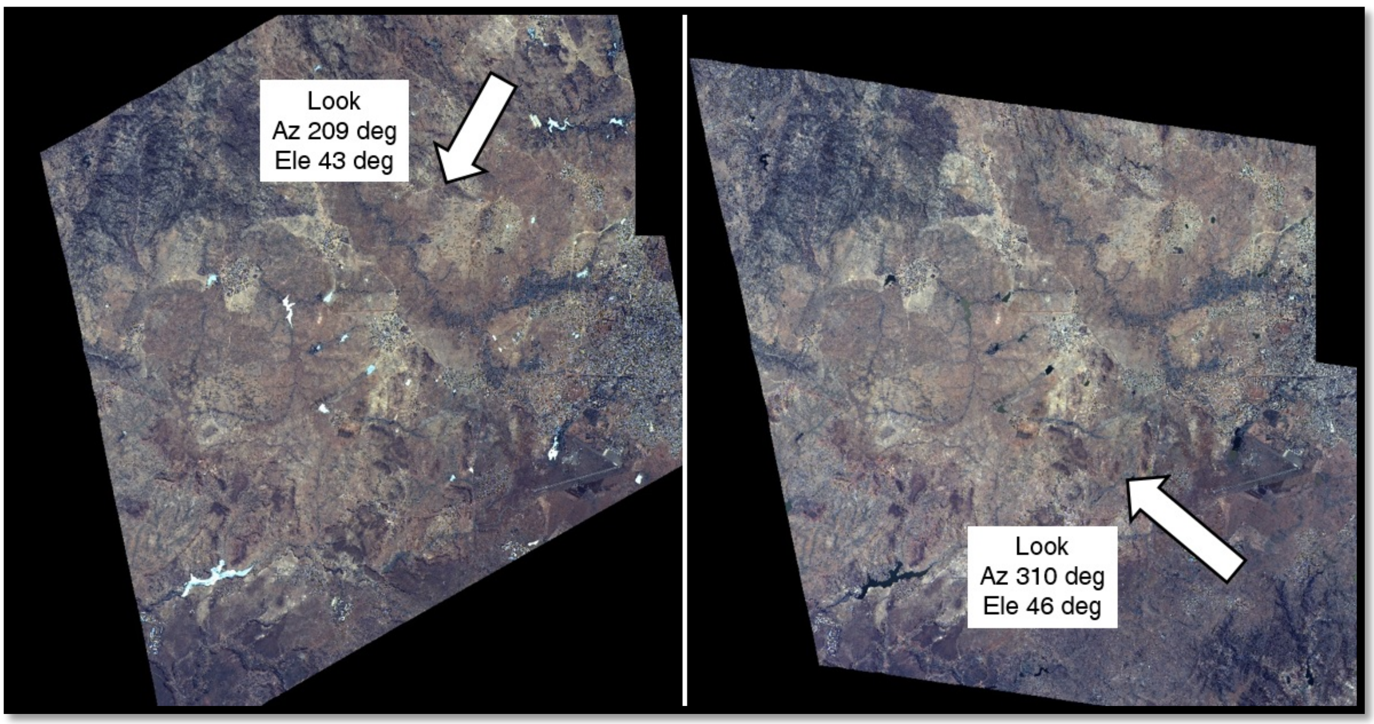

Figure 3. Kompsat-3A satellite photos of PhotoSat's Eritrea test area taken on October 31, 2016 at approximately 1:40 AM local time. The photo on the left was taken looking at an azimuth of 209 deg and angle from vertical of 43 deg. The photo on the right was taken looking at an azimuth of 310 deg and angle from vertical of 46 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 261 deg and bisector angle of 32 deg from vertical.

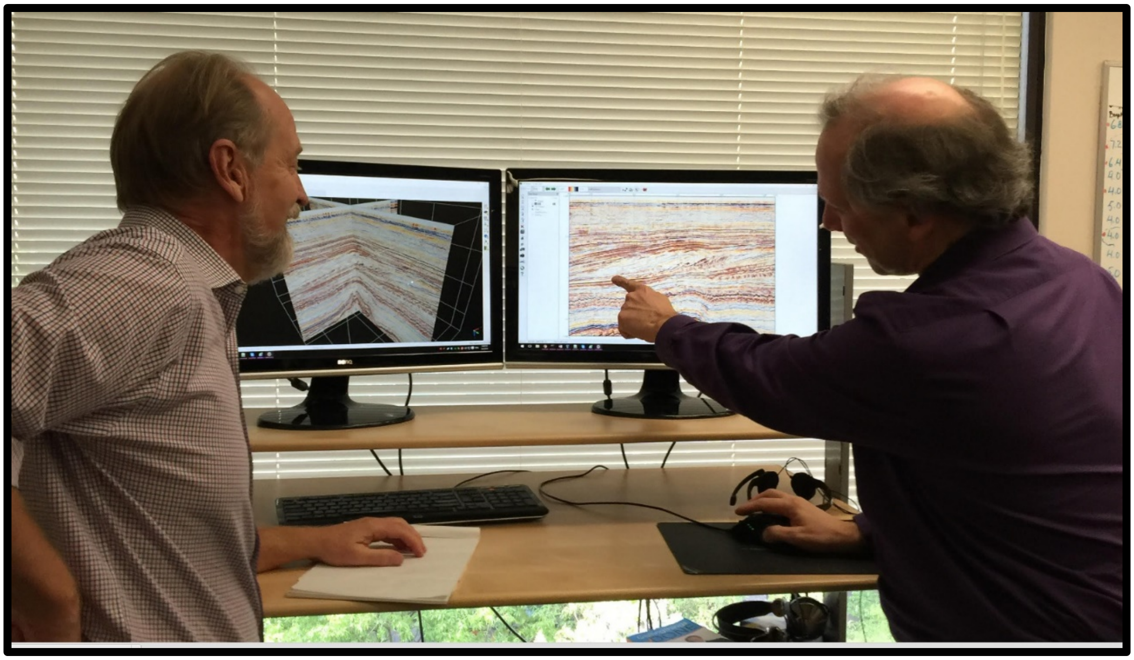

Figure 4. Gerry Mitchell, left and Michael Ehling with an Oil and Gas seismic processing workstation. This technology is the basis for the PhotoSat geophysical stereo satellite processing system named the PhotoSat Process Manager.

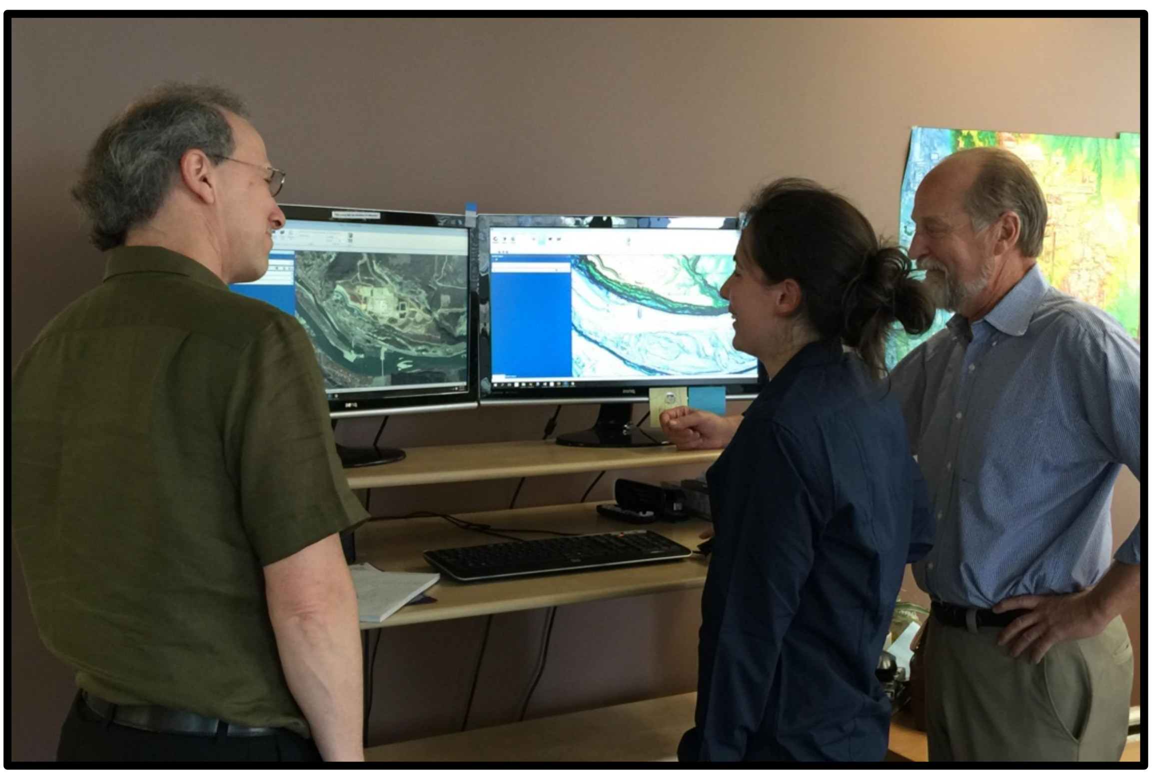

Figure 5. Michael, Gerry and Jayda Akatsuka with the PhotoSat Process Manager.

Eritrea elevation grid:

PhotoSat produced a 1m grid of elevations over the entire project area. We processed the stereo Kompsat-3A 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 Kompsat-3A surveys with only eleven ground reference points. Having eleven ground reference points for a 130 km^2 satellite surveying project is not uncommon in mining exploration projects.

The location of the ground reference points is shown in Figure 6.

Global shift of stereo satellite survey to match ground reference:

The Kompsat-3A ortho photo and elevation grid needed a constant shift of only -18.25m E, 21.0m N and -16.0m in elevation to match the ground surveying.

Accuracy evaluation checkpoints:

The accuracy of the PhotoSat 1m survey grid was evaluated with 1,406 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 checkpoints consist of a 250m by 250m regional grid of points. This can be seen in Figure 8.

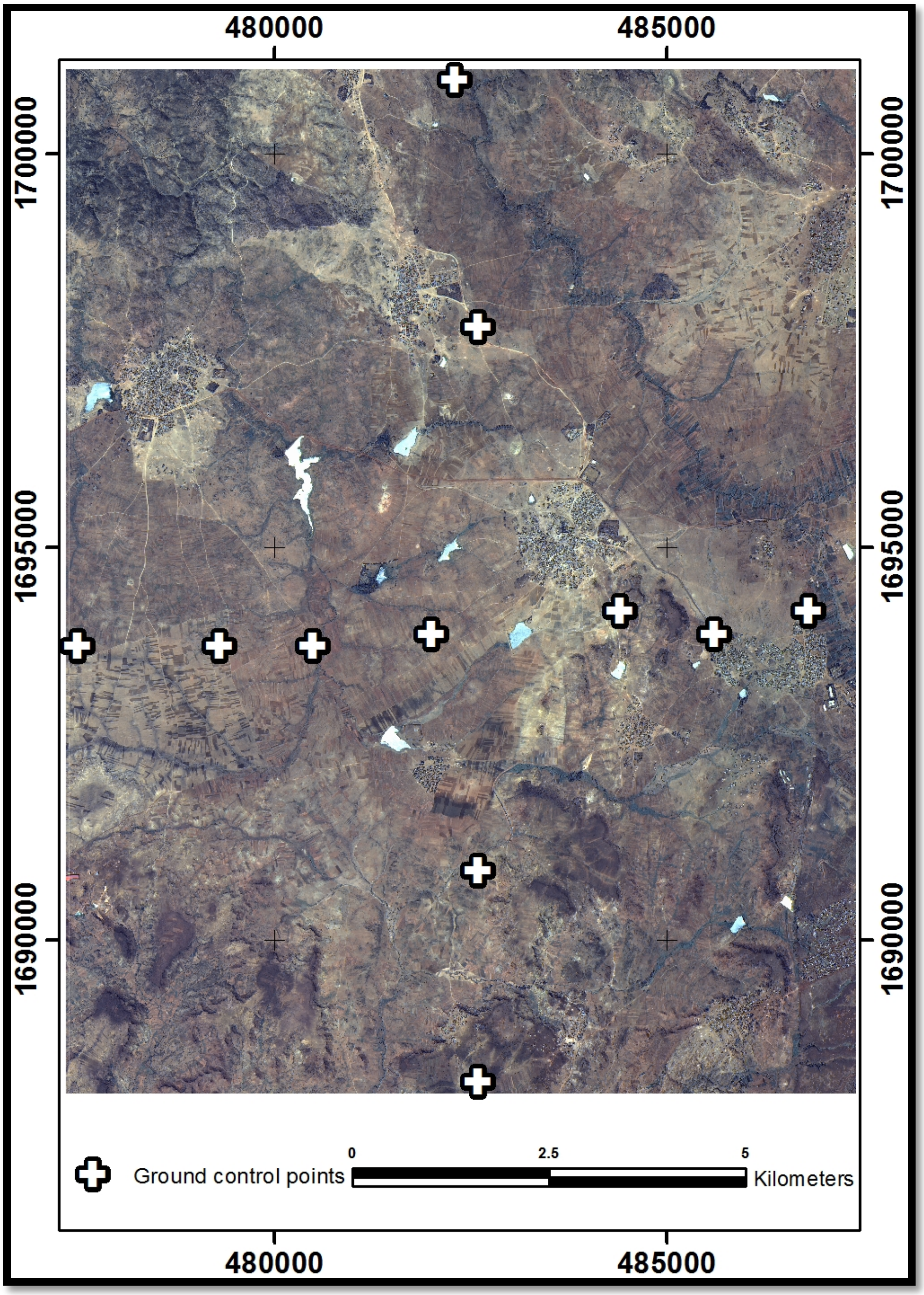

Figure 6. Kompsat-3A 50cm stereo satellite photo. Asmara, Eritrea.

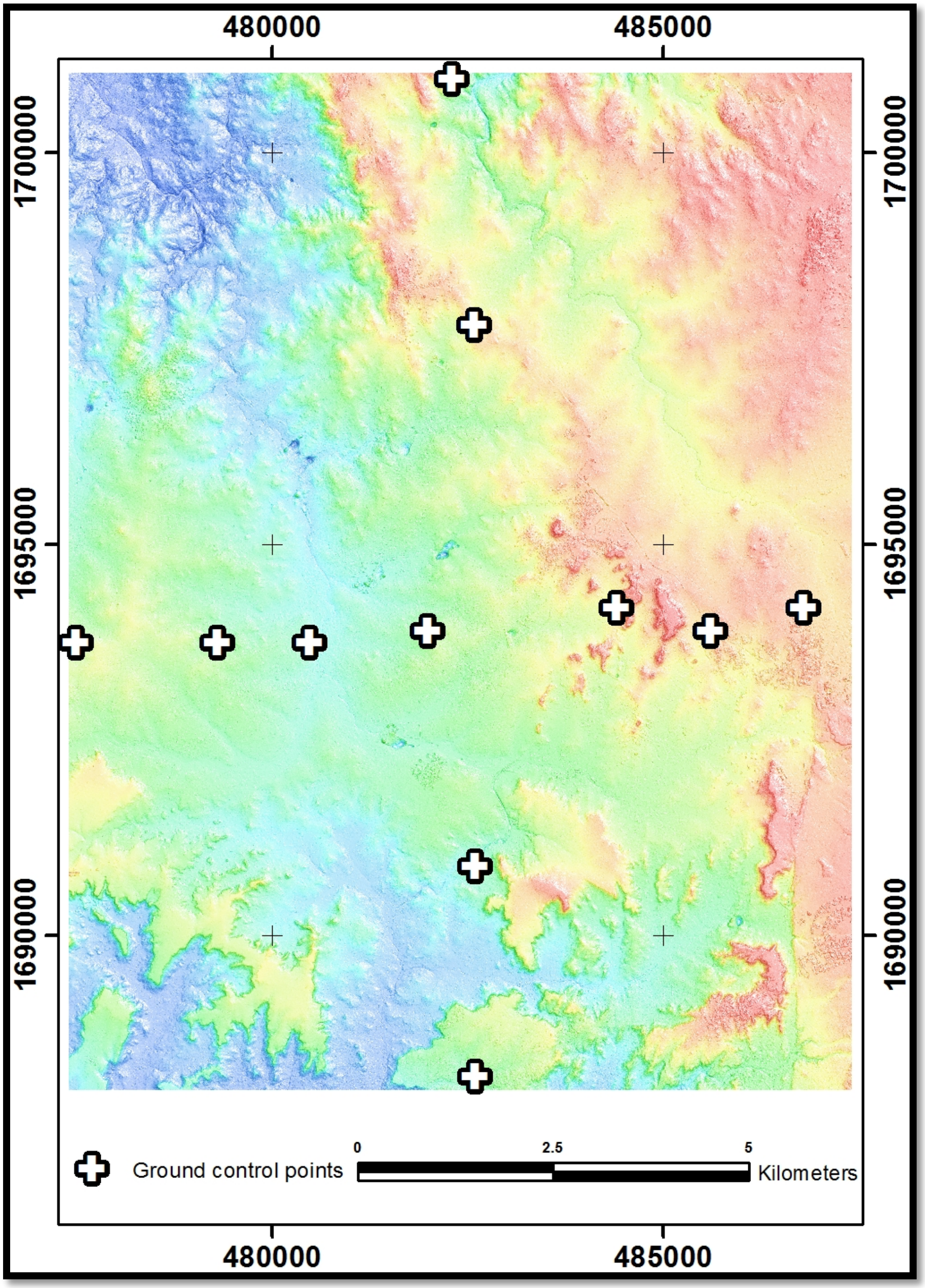

Figure 7. Stereo Kompsat-3A elevation image created from the 1m PhotoSat Asmara, Eritrea satellite survey grid. The figure shows the locations of the eleven ground control points.

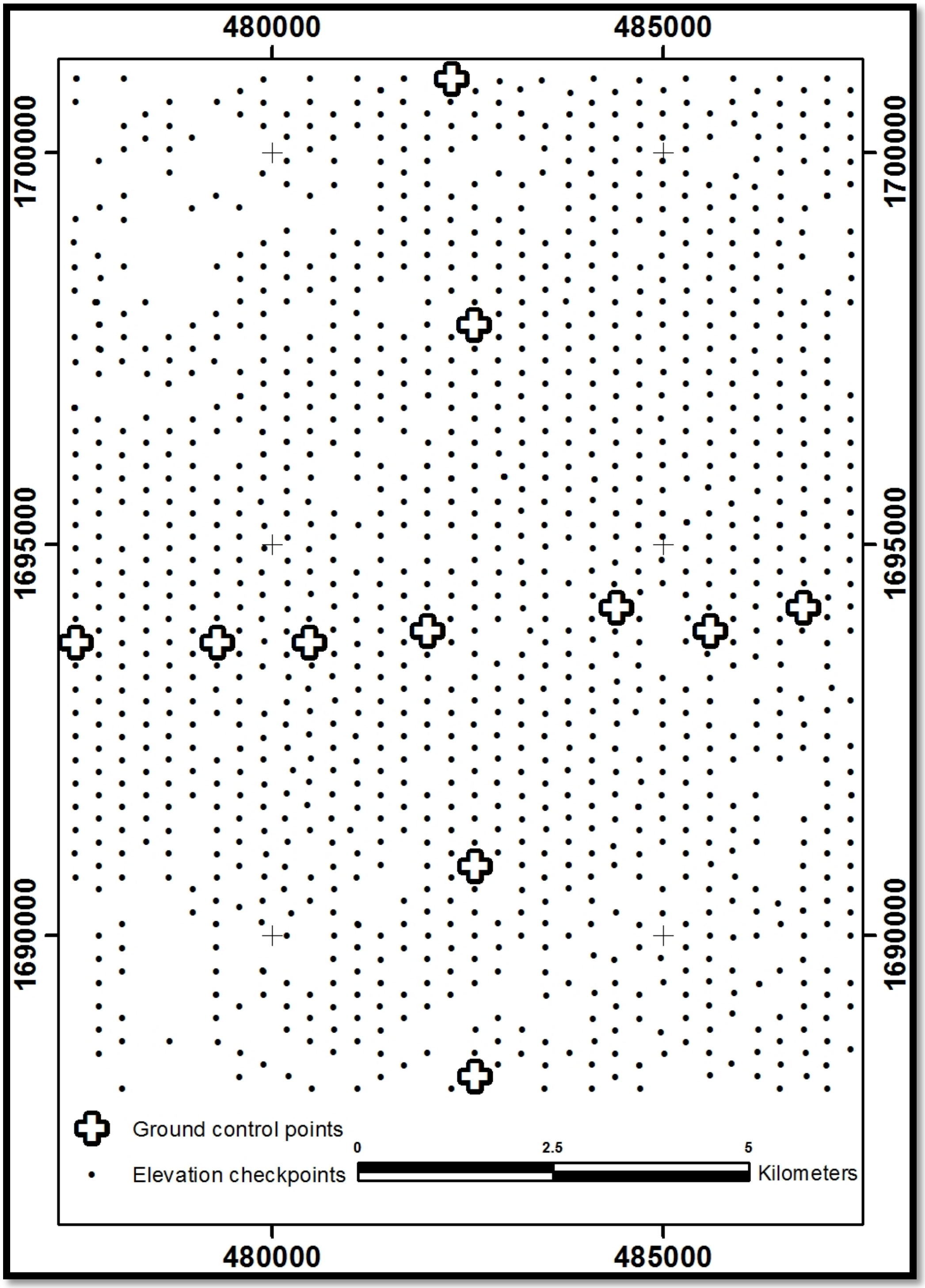

Figure 8. Area of the 13km by 10km Eritrea Stereo Kompsat-3A 1m elevation grid showing the ground control points and the 1,406 gravity survey stations used as elevation checkpoints to determine the accuracy of the stereo satellite survey.

Figure 9. Asmara Project, Eritrea. MWH Geo-Surveys differential GPS survey crew and equipment. The Magellan RTK base with a ProMark^{TM} 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 1,406 elevation checkpoints with slopes less than 20% grade have an RMSE of 48cm as shown in Figure 10.

A histogram of the elevation differences between the PhotoSat Kompsat-3A survey grid and all 1,597 ground survey check points is shown in Figure 11. The RMSE using all of the points is 62cm.

The points on slopes over 20% grade have an RMSE of 1.08m as shown in Figure 12.

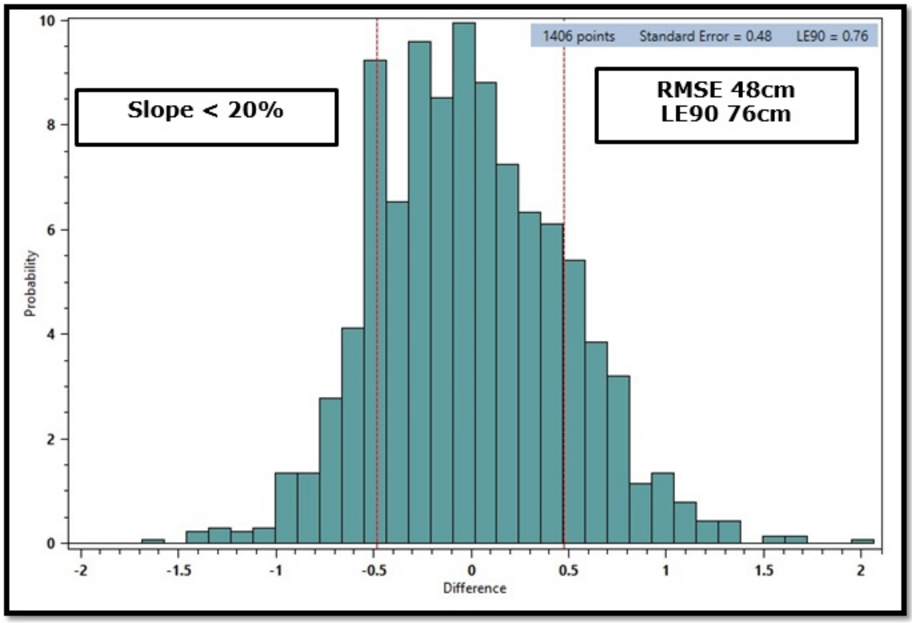

Figure 10. Histogram of the elevation differences between the Kompsat-3A stereo satellite elevations for the 13km by 10km area and the 1,406 elevation checkpoints with slopes less than 20% grade. The *Guidelines for Digital Elevation Data* of the US National Digital Elevation Program (NDEP) recommends that elevation checkpoints should be chosen in areas with slopes less than 20% grade. RMSE 48 cm, LE90 76cm.

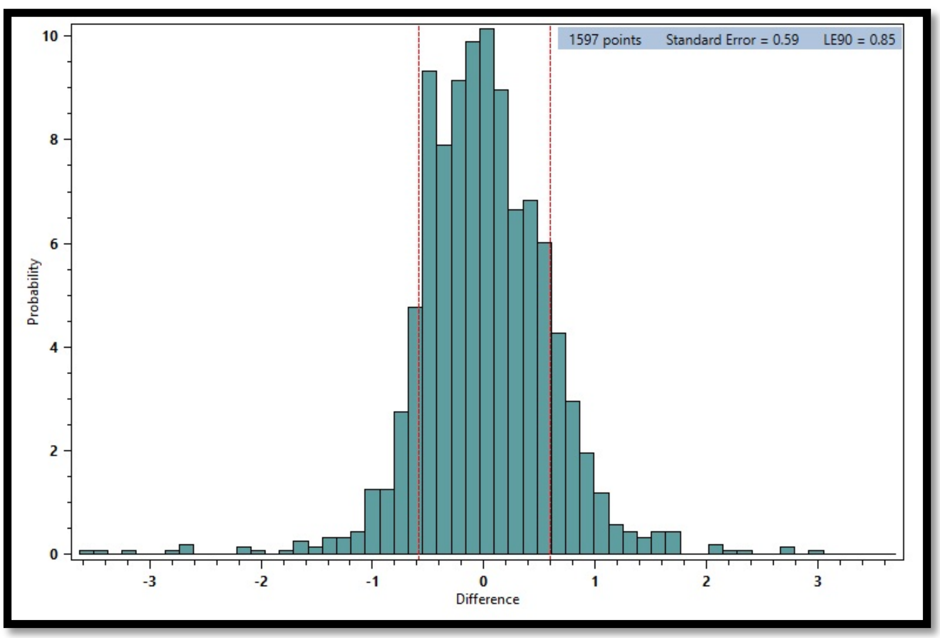

Figure 11. Histogram of the elevation differences between the Kompsat-3A stereo satellite elevations for the 13 km by 10km area and all 1,597 elevation checkpoints. RMSE 59cm, LE90 85cm.

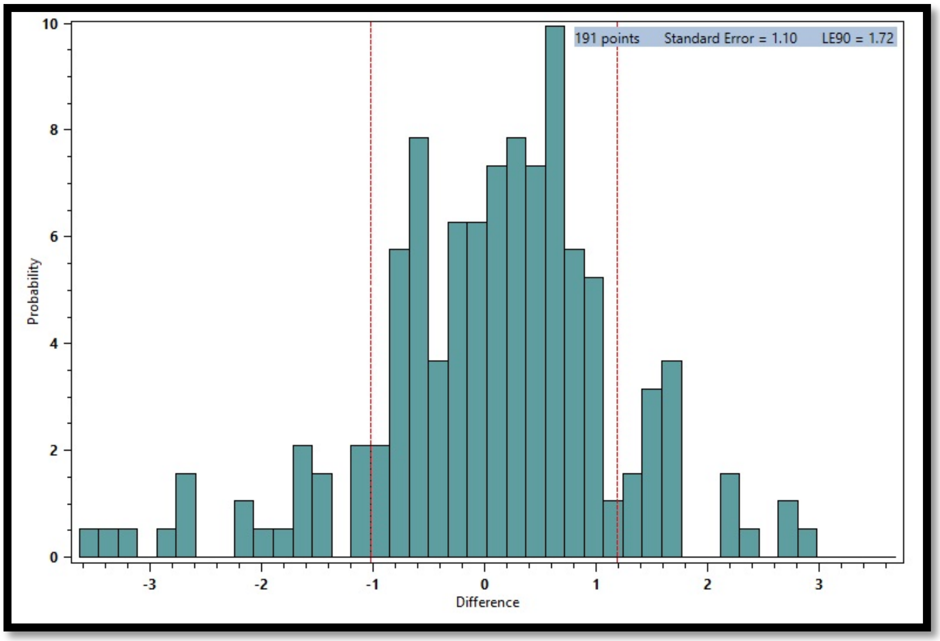

Figure 12. Histogram of the elevation differences between the Kompsat-3A satellite elevations for the 13 km by 10 km area and the 191 elevation checkpoints with slopes between 20% and 100% grade. RMSE 1.10m, LE90 1.72m.

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.

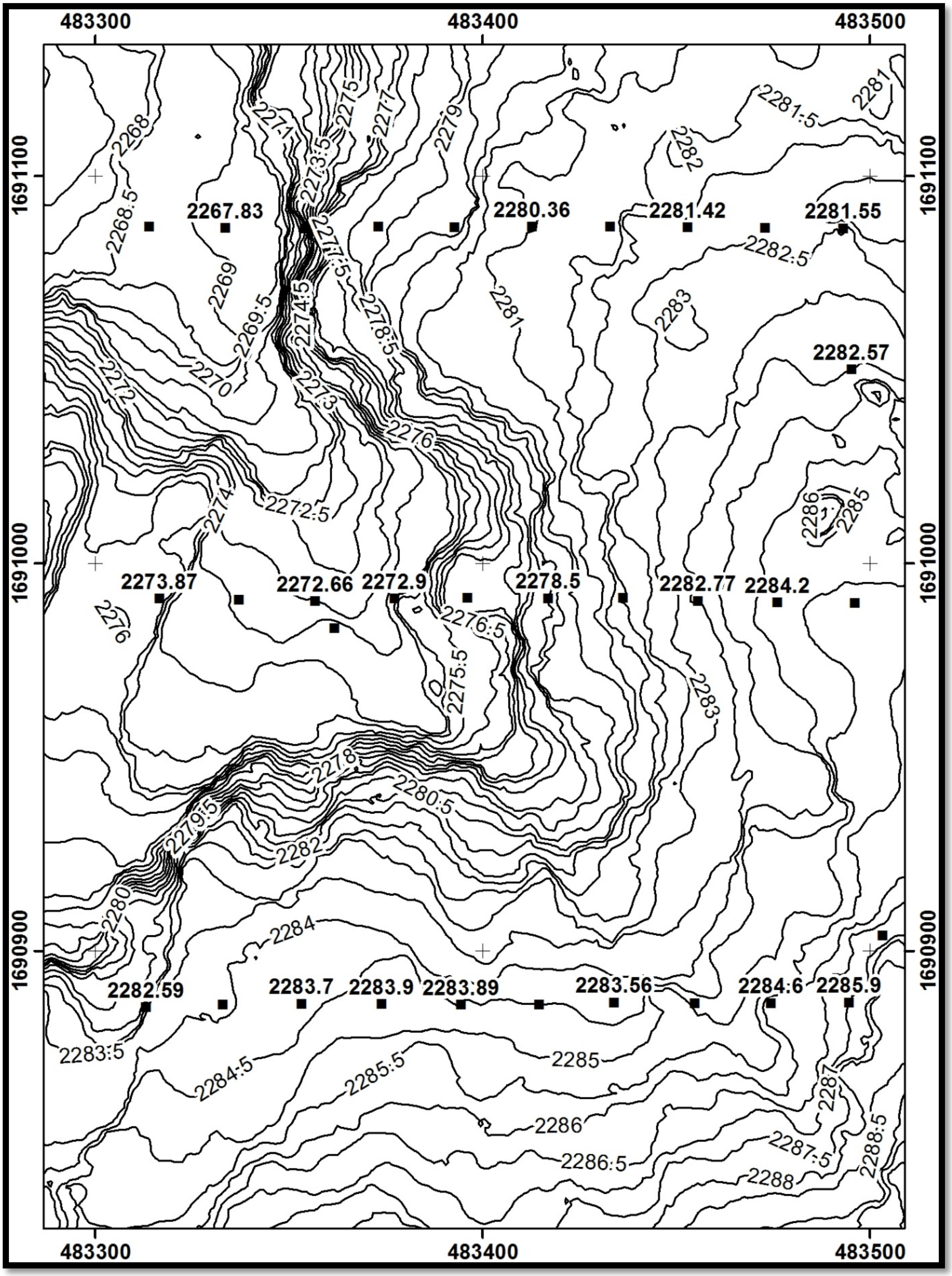

Figure 13. 50cm contours from the stereo Kompsat-3A elevation survey comparing the contour elevations to some of the elevation checkpoints.

Qualifying Statement:

This is an accuracy assessment for elevation mapping from a single stereo pair of Kompsat-3A satellite photos. While in our experience these results are typical for most Kompsat-3A stereo 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

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