

# **Topographic Survey Report**

For the

**MAËVA Group, Agricultural Development Project, Boane,  
Mozambique**

Prepared by:



**15 September 2016**

**Survey dates: 4 - 11 August 2016**

Client:

**MAËVA GROUP**

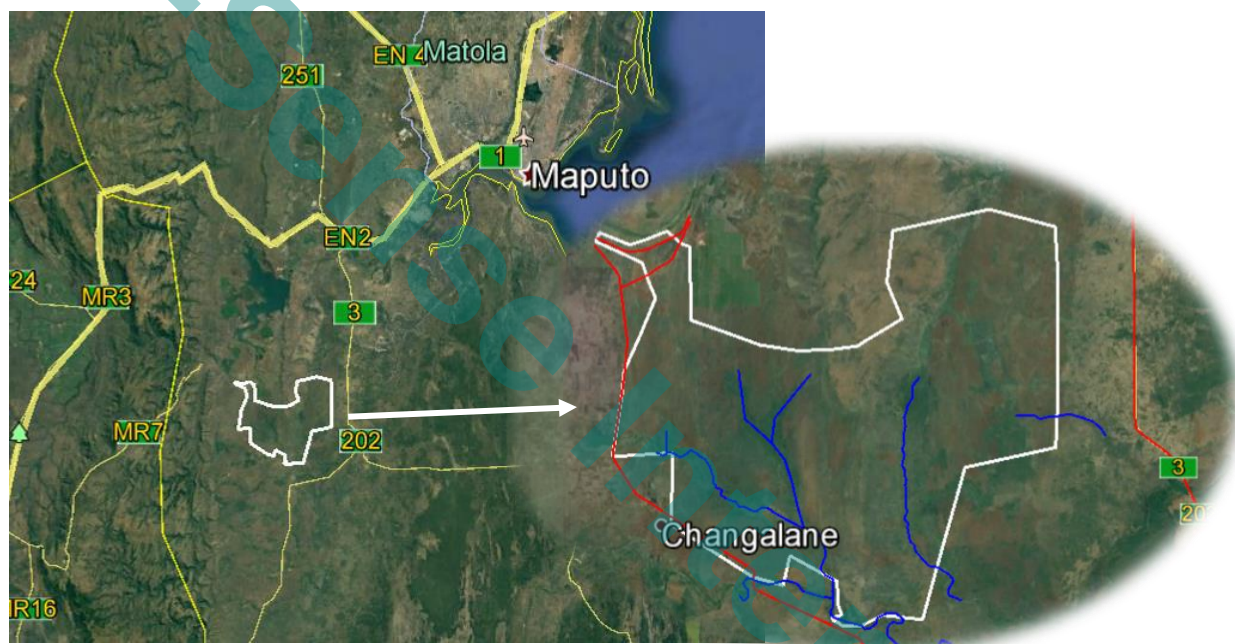
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## Introduction

The MAËVA group of companies is a major producer of high quality vegetable oils and natural soaps, based in Maputo, Mozambique. They are currently planning an Agricultural Development Project on 10 000 ha of land near Boane, in Southern Mozambique. The current objective of the project is to produce irrigated & dryland Maize ultimately to supply feed to a poultry farm to be incorporated within the farm boundary using a turnkey system imported from Israel.

Charlie Strachan is co-ordinating the project on behalf of MAËVA, and contacted Agri-Sense in conjunction with Agriscane to assist with the project.



*Image 1 : indicating the location of the project*

Survey and Soil Survey, which provides the foundation for future planning and development of the project.

Agri-Sense has conducted a full aerial survey of the property, and produced high resolution aerial ortho map as well as a digital terrain model & contours. The purpose of this is to provide accurate elevations for future planning of irrigation and bulk water supply, as well as drainage design, roads, buildings and other infrastructure planning.

The aerial survey was carried out using 2 Unmanned Aerial Vehicles (drones) in combination with ground survey using survey grade Trimble GPS equipment. The survey team consisted of Ross Walters, team leader and pilot, and Steve Wagner, land surveying and data processing, accompanied by Charlie Strachan, representing Maeva.

## Mobilisation and Site Scouting

The Agri-Sense Team departed from South Africa and arrived on site on the 3<sup>rd</sup> of August.

Accommodation was supplied by Maevea, at their facility in Matola, and was of a very good standard, with excellent food. Agri-Sense used their operations vehicle to travel to site each day which took approximately 45min-1 hr each way, and were supported by Maevea with a double cab pick which was used primarily by the land survey team.

On the 4<sup>th</sup> the team, after gathering supplies arrived on site at about 11am. From here they continued to scout the site for a suitable location to place the base station to operate from. Once the base site was established, the team continued to place and record the ground control points with the Trimble PPK survey kit.



*Image 2: The Team scouting for a suitable base station.*

The aerial survey was completed on the afternoon of the 11<sup>th</sup> August and the team returned to Durban on the 12<sup>th</sup> August to process the imagery.

## Methodology

Agri-Sense uses the latest in aerial survey technology, using Unmanned Aerial Vehicles (UAVs) in combination with terrestrial PPK/RTK GPS survey equipment to produce high resolution Ortho Maps (aerial photos), and detailed terrain data in the form of XYZ point clouds, 3D terrain models (DSMs/DTMs) and contour maps





*Image 3 : One of the UAVs shortly after take-off.*

The terrestrial survey team uses the PPK/RTK GPS to place numerous ground control points within the target area that are visible from the air. The area is then flown with the UAV, and imagery is collected and processed together with ground control data, using powerful aerial photogrammetry software to achieve very high levels of accuracy.



*Image 4 : Ground Control Point (GCP) made using Agricultural lime.*

## Aerial Survey

weather conditions were acceptable throughout most of the aerial survey, except for high winds during the first few days, which limited the amount of flying that could be done. Light conditions were very good during the aerial survey and allowed for the pilot to catch up and finish on schedule.

The aerial survey was completed with the use of 2 SenseFly Ebee, UAVs. In total 68 flights were carried out over the area, with each flight lasting approximately 30 minutes, and an average of 250 photos taken per flight. Images were taken at an average altitude of 265 m above ground level with a grid spacing of 110m between flight lines and 55m between photographs. Flights lines were set out to run in a North South direction.

The entire area was flown from 5 take-off and landing sites, and did not attract and serious attention or interest from locals on site. No incidents accidents or damages were reported, however one of the drones did get attacked by a falcon, but did not receive any damage, and the falcon was seen flying normally thereafter.

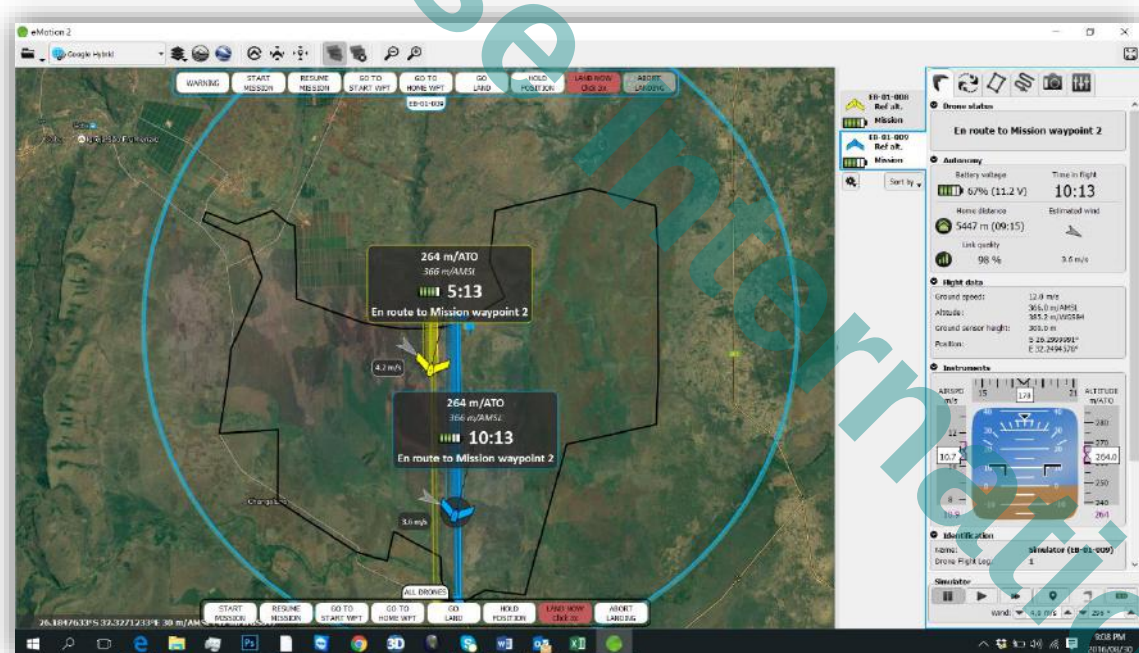


Image 5 : Screen shot of the flight control program

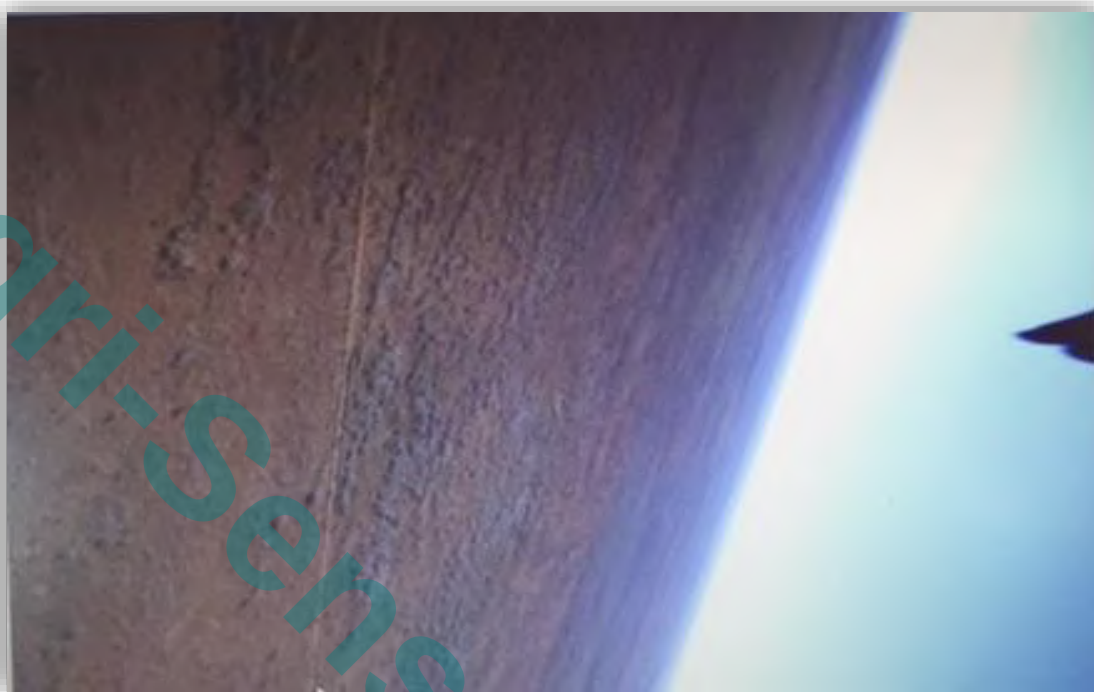


Image 6 : Picture taken during the falcon attack (note the falcon's wing tip on the right)

The sites were divided into 4 blocks for the purposes of efficient flying and processing.

| Block Number  | Dates Flown            | Missions Flown | Gross Area surveyed | Comments                    |
|---------------|------------------------|----------------|---------------------|-----------------------------|
| West Block    | 06, 07, 09 August 2016 | 35             | 4736                | Clear & windy to very windy |
| Central Block | 10-Aug                 | 14             | 2776                | Clear and Calm              |
| East Block    | 11-Aug                 | 19             | 3570                | Clear and Calm              |
|               |                        |                |                     | avg ha / flight             |
|               | <b>TOTAL</b>           | <b>68</b>      | <b>11082</b>        | <b>163</b>                  |

Table 1: Summary of Survey Blocks

The weather experienced during the 10 days on site was acceptable for aerial survey. As is typical during this time of year in Southern Mozambique, weather conditions were influenced by cold fronts which usually follow 6-10-day cycle. Although there was no rain during our time on site, overcast and windy conditions occurred from the 3rd to the 5th, during which time we focused on the land survey of the



property. With the passing of the cold front, conditions remained windy with brisk to strong Southerly winds reaching 25-35 kts. This did effect the potential for flying for 2 days, by reducing the flight times of the drones. Atmospheric Conditions then stabilized and wind direction switch to a light to moderate Northerly, accompanied by fine clear weather for the remainder of the survey. As is typical with this type weather occasion cumulus clouds formed during the afternoons, but had little impact on the quality of the imagery. Good decisions and understanding of the conditions by the team on site meant that the weather had very little impact on the survey.



*Image 7 Image showing the cloudy conditions*

At the end of day 10 the team left site. The Agri-Sense team returned to South Africa on the 12<sup>th</sup> August to process the imagery.



## Terrestrial Survey

Land surveying involves establishing ground control points (GCPs), which are made by drawing a white cross on the ground with whitewash and then recording the position and elevation of each point with the Trimble GPS. These points are then used to calibrate the aerial imagery and correct the accuracy of the map to international survey standards.

In total 114 GCPs were established across the property. Due to the lack of roads most of the GCPs were reached by foot. The Land surveying team were assisted by a driver and 2 labourers supplied by Maeva. The labour were used to help carry the white wash and to guard the GPS base station. The ground control points took 6 days to complete.

The survey was done on the world geodetic system. The Survey Team calibrated the Trimble RTK GPS unit on WGS'84 Datum, UTM Projection Zone 36S. The calibration file is attached on Appendix 4. Height system was adjusted for Geoid Separation using NGA EGM 2008 Geoid Calculator. No national height coordinated beacons were found in the area.

A geoid separation of 20.10m was calculated for the site. The adjusted figures conformed to Google Earth Heights and the Project Specified Heights.



*Image 8 Measuring the Ground control points*

The whole survey was done using a Trimble R4 PPK Smart GPS unit. The technical specifications and accuracy reports are included in the Appendix 5 & 4 respectively.

The geographical locations of the Ground Control Points are attached to Appendix 3. Data processing was done using Trimble Business Centre (TBC) software.

## Data Processing

The processing of all the flight data was done using Pix4D photogrammetric software. The project area was divided into 4 blocks for processing as per the flight data.

At the first stage of processing the images are processed using an “Initial Process” where all images are matched and the elevations are corrected to the ground control points. This is to establish how accurate their matching is relative to the surrounding images, along with their elevations and the visibility of the ground (Clarity). Re-optimisation and re- matching are carried out until the results are acceptable.

The second stage of processing is the actual development of the map image and the surface model.

Quality reports are generated at the end of stage 1 and are attached in Appendix 1. These reports explain how accurate the final maps have the potential to be, and are summarised in table 2 below

| Processing Variables                                   | Processing      |
|--------------------------------------------------------|-----------------|
|                                                        | Maeva Main Area |
| Initial Processing date                                | 23 Aug 2016     |
| Time taken for initial process (h)                     | 7d 13h 06m      |
| Orthomosaic/DSM generation time (h)                    | 2d 16h 43m      |
| Image Editing time (h)                                 | 10 days         |
| Average Ground Sampling Distance (cm)                  | 7.67            |
| Image coordinate system                                | WGS84/UTM       |
| Output Coordinate system                               | WGS84/UTM 36S   |
| <b>Quality Check</b>                                   |                 |
| Image Keypoints per Image                              | 21302           |
| Dataset -Image Calibration                             | 99%             |
| Camera Optimization (Focal Length Relative Difference) | 0.08%           |
| Matching - Matches per Calibrated image                | 5819            |
| Georeferencing (m)                                     | 1.559m          |

**Table 2:** Showing Processing summary refer to appendix 2 for explanations

The keypoints per image are all well above the 10 000 recommended minimum, with the image calibration above 99%. Camera optimisation for all blocks were excellent and well below the 5% maximum. Matches per calibrated image are very good, well above the 1000 acceptable minimum. Georeferencing displays how the imagery was conformed to the GCP's, to improve the accuracy of the map. Although this number may seem high at 1.559m, it merely states that some of the GCP's corrected the images around them by that much reiterating the need for accurate GCPs. This was only found to be the case for 4 GCP's, these were verified to make sure they were correct.

## Deliverables

The following data has been completed and submitted in digital format as part of this report,

- RGB Orthomosaic Image of the AOIs or at a resolution of 7.5cm GSD
- Digital Elevation Model DEM of the development area.
- Point cloud of the entire area in LAZ file formats.
- 0.5m contours in DWG / DXF format or in any CAD format for engineering designs
- Location of Ground Control Points, Appendix 3
- PPK Calibration Files, Appendix 4
- Processing report and descriptions, Appendix 1 & 2,
- Trimble R4 GNSS GPS Specs, see Appendix 5,

## Summary

Technically, the aerial and ground survey was carried out well. Logistically there were some challenges. Thick vegetation, limited road access in the area slowed down the pace and was compounded overcast and windy conditions.

The team from Maeva performed well and although surprised by the long hours and distances walked each day, were helpful and willing. Moral on site remained high most of the time, mainly thanks to presence of Charlie Strachan.

Additional observations made on site, include the good quality of the soils that predominate across most of the area. The lack of wildlife, and absence of large hard wood trees. Numerous animal traps and snares, and evidence of continued illegal wood harvesting and charcoal making on the property. There are numerous herds of cattle that roam the property. There seems to be a good understanding of where the boundaries of the property are from the local communities but there is some encroachment taking place along the boundaries, in the form of small scale cultivation of crops and grazing. We encountered little evidence of people living on the property.

Processing was completed successfully and clear imagery with an accurate 3D model was produced. Although there were logistical problems on site the local people were very hospitable and all the above mentioned comment did not impact the results or deadline.

## **Appendix 1**

### Image Processing Report



# Quality Report



Generated with Pro version 2.2.22



**Important:** Click on the different icons for:



Help to analyze the results in the Quality Report



Additional information about the sections



Click [here](#) for additional tips to analyze the Quality Report

## Summary



|                                        |                                                                        |
|----------------------------------------|------------------------------------------------------------------------|
| Project                                | mae61_all_sw_2222_20160815                                             |
| Processed                              | 2016-08-24 11:32:58                                                    |
| Camera Model Name(s)                   | DSC-WX220_4.4_4896x3672 (RGB)                                          |
| Average Ground Sampling Distance (GSD) | 7.67 cm / 3.02 in                                                      |
| Area Covered                           | 111.873 km <sup>2</sup> / 11187.3 ha / 43.2167 sq. mi. / 27658.7 acres |

## Quality Check



|                     |                                                                                    |  |
|---------------------|------------------------------------------------------------------------------------|--|
| Images              | median of 21302 keypoints per image                                                |  |
| Dataset             | 14167 out of 14170 images calibrated (99%), all images enabled, 2 blocks           |  |
| Camera Optimization | 0.21% relative difference between initial and optimized internal camera parameters |  |
| Matching            | median of 5808.86 matches per calibrated image                                     |  |
| Georeferencing      | yes, 114 GCPs (114 3D), mean RMS error = 1.559 m                                   |  |

## Preview

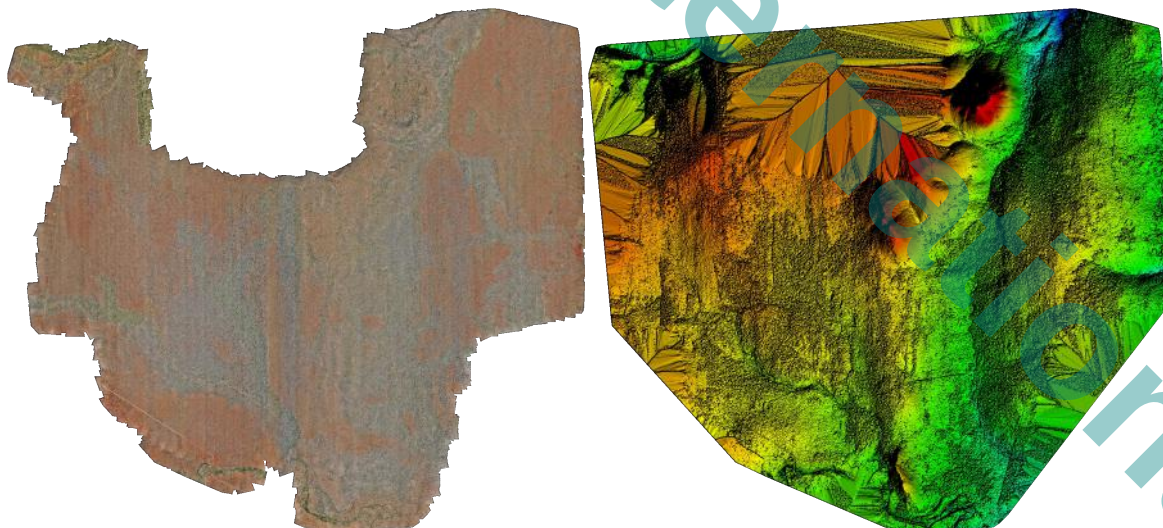


Figure 1: Orthomosaic and the corresponding sparse Digital Surface Model (DSM) before densification.

## Calibration Details



|                             |                    |
|-----------------------------|--------------------|
| Number of Calibrated Images | 14167 out of 14170 |
| Number of Geolocated Images | 14170 out of 14170 |

## Initial Image Positions

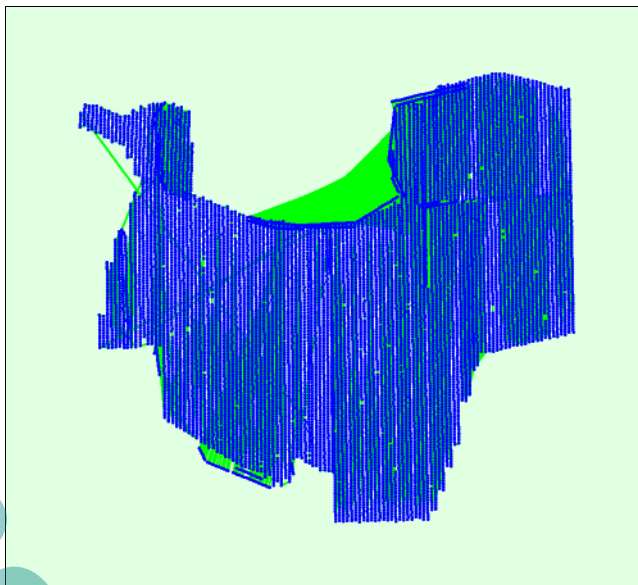
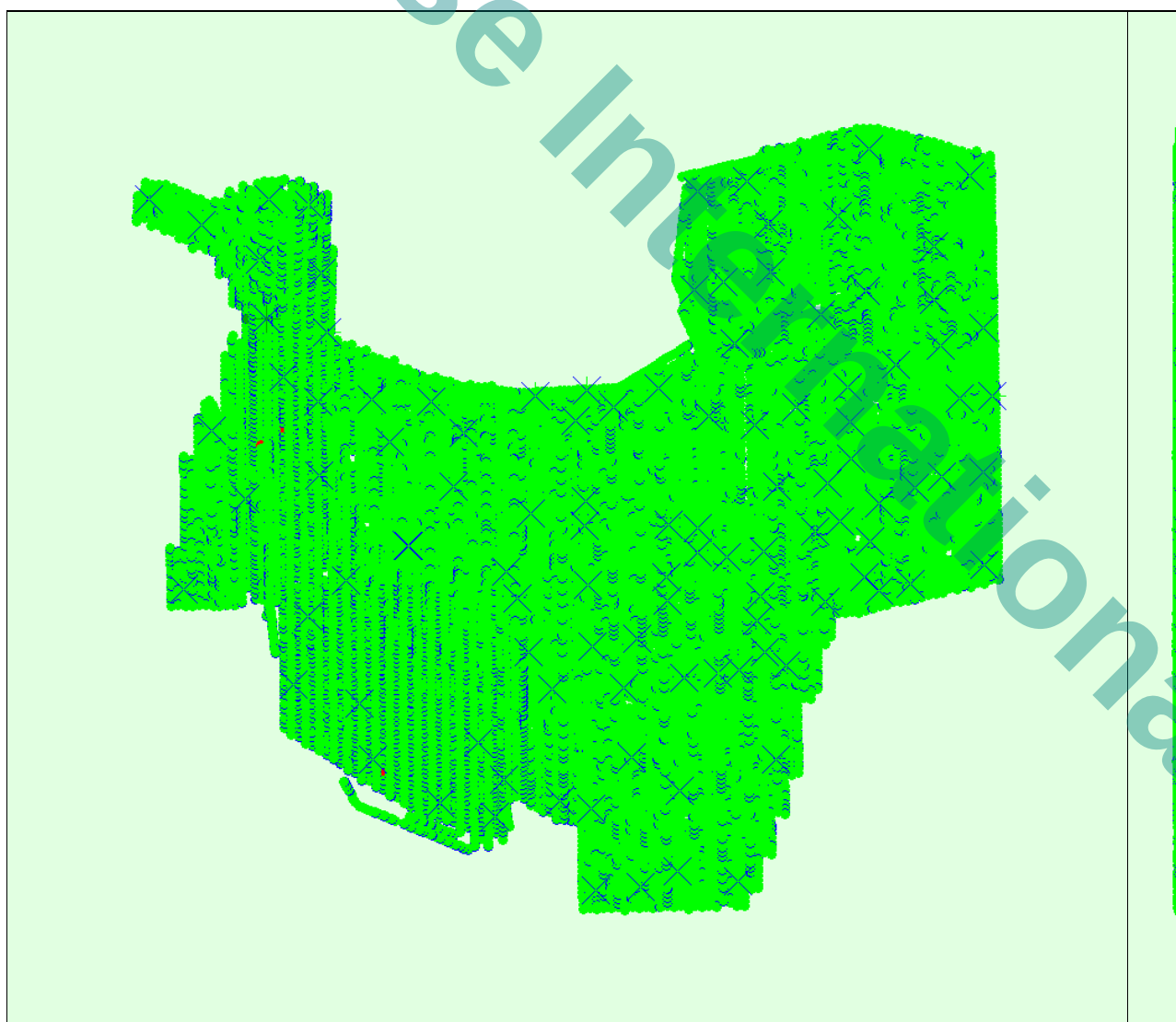


Figure 2: Top view of the initial image position. The green line follows the position of the images in time starting from the large blue dot.

## Computed Image/GCPs/Manual Tie Points Positions



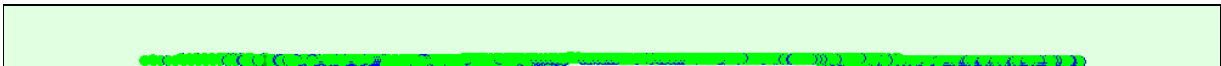


Figure 3: Offset between initial (blue dots) and computed (green dots) image positions as well as the offset between the GCPs initial positions (blue crosses) and their computed positions (green crosses) in the top-view (XY plane), front-view (XZ plane), and side-view (YZ plane). Red dots indicate disabled or uncalibrated images.

Overlap

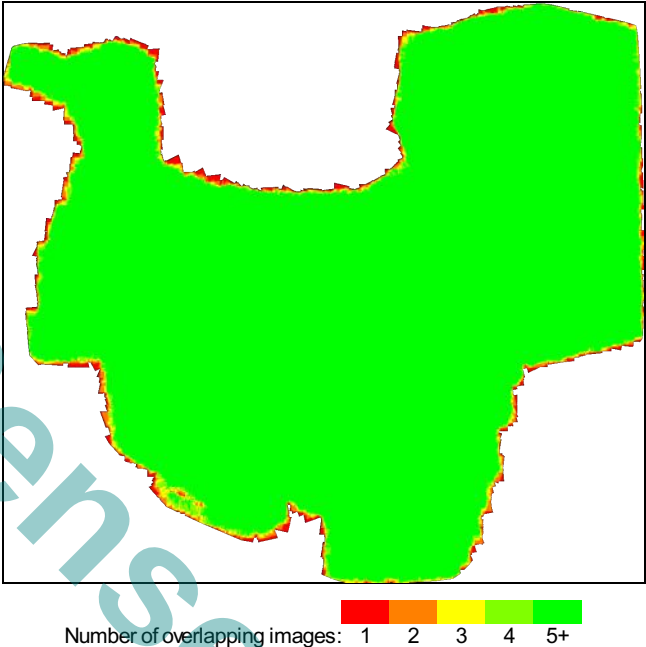


Figure 4: Number of overlapping images computed for each pixel of the orthomosaic. Red and yellow areas indicate low overlap for which poor results may be generated. Green areas indicate an overlap of over 5 images for every pixel. Good quality results will be generated as long as the number of keypoint matches is also sufficient for these areas (see Figure 5 for keypoint matches).

Bundle Block Adjustment Details

|                                                                |          |
|----------------------------------------------------------------|----------|
| Number of 2D Keypoint Observations for Bundle Block Adjustment | 90437306 |
| Number of 3D Points for Bundle Block Adjustment                | 32808622 |
| Mean Reprojection Error [pixels]                               | 0.141    |

Internal Camera Parameters

DSC-WX220\_4.4\_4896x3672 (RGB). Sensor Dimensions: 6.170 [mm] x 4.627 [mm]

EXIF ID: DSC-WX220\_4.4\_4896x3672

|                  | Focal Length                   | Principal Point x              | Principal Point y              | R1    | R2     | R3    | T1    | T2    |
|------------------|--------------------------------|--------------------------------|--------------------------------|-------|--------|-------|-------|-------|
| Initial Values   | 3628.284 [pixel]<br>4.572 [mm] | 2447.997 [pixel]<br>3.085 [mm] | 1836.004 [pixel]<br>2.314 [mm] | 0.012 | -0.045 | 0.050 | 0.005 | 0.003 |
| Optimized Values | 3636.090 [pixel]<br>4.582 [mm] | 2472.833 [pixel]<br>3.116 [mm] | 1873.447 [pixel]<br>2.361 [mm] | 0.005 | -0.030 | 0.025 | 0.003 | 0.002 |



The number of Automatic Tie Points (ATPs) per pixel averaged over all images of the camera model is color coded between black and white. White indicates that, in average, more than 16 ATPs are extracted at this pixel location. Black indicates that, in average, 0 ATP has been extracted at this pixel location. Click on the image to see the average direction and magnitude of the reprojection error for each pixel. Note that the vectors are scaled for better visualization.

## 2D Keypoints Table



|        | Number of 2D Keypoints per Image | Number of Matched 2D Keypoints per Image |
|--------|----------------------------------|------------------------------------------|
| Median | 21302                            | 5809                                     |
| Min    | 9993                             | 30                                       |
| Max    | 40783                            | 21972                                    |
| Mean   | 21333                            | 6384                                     |

## 3D Points from 2D Keypoint Matches



|              | Number of 3D Points Observed |
|--------------|------------------------------|
| In 2 Images  | 20835943                     |
| In 3 Images  | 6346303                      |
| In 4 Images  | 2689802                      |
| In 5 Images  | 1259967                      |
| In 6 Images  | 662457                       |
| In 7 Images  | 391006                       |
| In 8 Images  | 241497                       |
| In 9 Images  | 147267                       |
| In 10 Images | 89640                        |
| In 11 Images | 55665                        |
| In 12 Images | 35806                        |
| In 13 Images | 22679                        |
| In 14 Images | 13582                        |
| In 15 Images | 7845                         |
| In 16 Images | 4330                         |
| In 17 Images | 2276                         |
| In 18 Images | 1122                         |
| In 19 Images | 635                          |
| In 20 Images | 334                          |
| In 21 Images | 206                          |
| In 22 Images | 112                          |
| In 23 Images | 58                           |
| In 24 Images | 44                           |
| In 25 Images | 27                           |
| In 26 Images | 16                           |
| In 28 Images | 3                            |

## 2D Keypoint Matches





Number of matches 25 222 444 666 888 1111 1333 1555 1777 2000

Figure 5: Computed image positions with links between matched images. The darkness of the links indicates the number of matched 2D keypoints between the images. Bright links indicate weak links and require manual tie points or more images.

## Geolocation Details

### Ground Control Points

| GCP Name   | Accuracy XY/Z [m] | Error X [m] | Error Y [m] | Error Z [m] | Projection Error [pixel] | Verified/Marked |
|------------|-------------------|-------------|-------------|-------------|--------------------------|-----------------|
| GCP1 (3D)  | 0.020/ 0.020      | -0.108      | 0.117       | -0.006      | 1.188                    | 15 / 15         |
| GCP2 (3D)  | 0.020/ 0.020      | 0.066       | 0.098       | 0.010       | 0.985                    | 12 / 12         |
| GCP3 (3D)  | 0.020/ 0.020      | 0.020       | 0.113       | 0.093       | 1.176                    | 11 / 11         |
| GCP4 (3D)  | 0.020/ 0.020      | -0.074      | 0.128       | 0.010       | 0.840                    | 17 / 17         |
| GCP5 (3D)  | 0.020/ 0.020      | -0.037      | 0.095       | 0.070       | 0.890                    | 12 / 12         |
| GCP6 (3D)  | 0.020/ 0.020      | 0.015       | 0.049       | 0.065       | 0.720                    | 17 / 17         |
| GCP7 (3D)  | 0.020/ 0.020      | -0.004      | 0.031       | 0.004       | 0.851                    | 10 / 10         |
| GCP8 (3D)  | 0.020/ 0.020      | -0.009      | -0.060      | -0.020      | 1.328                    | 14 / 14         |
| GCP9 (3D)  | 0.020/ 0.020      | 0.180       | 0.175       | -0.087      | 1.097                    | 13 / 13         |
| GCP10 (3D) | 0.020/ 0.020      | -3.187      | 8.794       | -2.809      | 1.334                    | 11 / 11         |
| GCP11 (3D) | 0.020/ 0.020      | 6.896       | 12.580      | -0.549      | 0.778                    | 13 / 13         |



|            |              |         |        |        |       |         |
|------------|--------------|---------|--------|--------|-------|---------|
| GCP13 (3D) | 0.020/ 0.020 | 0.244   | 0.286  | 0.001  | 2.976 | 14 / 14 |
| GCP14 (3D) | 0.020/ 0.020 | -0.110  | 0.068  | 0.054  | 1.679 | 12 / 12 |
| GCP15 (3D) | 0.020/ 0.020 | -0.025  | 0.012  | -0.119 | 2.861 | 6 / 12  |
| GCP16 (3D) | 0.020/ 0.020 | 0.070   | -0.001 | -0.028 | 0.810 | 12 / 12 |
| GCP17 (3D) | 0.020/ 0.020 | 0.038   | 0.097  | 0.041  | 1.108 | 11 / 11 |
| GCP18 (3D) | 0.020/ 0.020 | -0.093  | 0.203  | 0.023  | 1.274 | 12 / 12 |
| GCP19 (3D) | 0.020/ 0.020 | -14.101 | 8.762  | -0.601 | 1.051 | 20 / 20 |
| GCP20 (3D) | 0.020/ 0.020 | 0.009   | -0.105 | -0.005 | 2.147 | 8 / 12  |
| GCP21 (3D) | 0.020/ 0.020 | 1.889   | 0.133  | 1.456  | 0.711 | 18 / 18 |
| GCP22 (3D) | 0.020/ 0.020 | 0.030   | -0.169 | -0.001 | 2.472 | 10 / 10 |
| GCP23 (3D) | 0.020/ 0.020 | -0.003  | -0.002 | -0.014 | 0.602 | 16 / 16 |
| GCP24 (3D) | 0.020/ 0.020 | 0.017   | -0.003 | -0.001 | 1.106 | 13 / 13 |
| GCP25 (3D) | 0.020/ 0.020 | -0.193  | -0.066 | 0.084  | 1.077 | 14 / 14 |
| GCP26 (3D) | 0.020/ 0.020 | 0.022   | -0.011 | -0.015 | 0.703 | 22 / 22 |
| GCP27 (3D) | 0.020/ 0.020 | 0.033   | -0.013 | -0.030 | 1.125 | 22 / 22 |
| GCP28 (3D) | 0.020/ 0.020 | 0.029   | -0.019 | 0.012  | 0.739 | 22 / 22 |
| GCP29 (3D) | 0.020/ 0.020 | 0.044   | -0.111 | 0.031  | 0.400 | 8 / 8   |
| GCP30 (3D) | 0.020/ 0.020 | -0.039  | 0.012  | 0.005  | 0.633 | 16 / 16 |
| GCP31 (3D) | 0.020/ 0.020 | -0.042  | 0.013  | 0.027  | 0.807 | 16 / 16 |
| GCP32 (3D) | 0.020/ 0.020 | 0.013   | 0.083  | 0.021  | 0.548 | 9 / 9   |
| GCP33 (3D) | 0.020/ 0.020 | -3.022  | 1.130  | -0.072 | 0.595 | 11 / 11 |
| GCP34 (3D) | 0.020/ 0.020 | -0.010  | 0.033  | 0.003  | 0.551 | 11 / 11 |
| GCP35 (3D) | 0.020/ 0.020 | 0.004   | 0.010  | 0.000  | 0.315 | 12 / 12 |
| GCP36 (3D) | 0.020/ 0.020 | 0.015   | -0.066 | -0.010 | 0.578 | 12 / 12 |
| GCP37 (3D) | 0.020/ 0.020 | -0.018  | 0.008  | 0.010  | 0.935 | 19 / 19 |
| GCP38 (3D) | 0.020/ 0.020 | 0.014   | 0.025  | -0.010 | 0.798 | 14 / 14 |
| GCP39 (3D) | 0.020/ 0.020 | 0.003   | -0.011 | -0.021 | 0.797 | 10 / 10 |
| GCP40 (3D) | 0.020/ 0.020 | -0.097  | -0.086 | -0.031 | 0.584 | 7 / 7   |
| GCP41 (3D) | 0.020/ 0.020 | 0.128   | -0.017 | 0.018  | 0.882 | 13 / 13 |
| GCP42 (3D) | 0.020/ 0.020 | -0.002  | -0.002 | -0.004 | 0.617 | 10 / 11 |
| GCP43 (3D) | 0.020/ 0.020 | 0.001   | -0.025 | -0.034 | 1.264 | 14 / 14 |
| GCP44 (3D) | 0.020/ 0.020 | -0.024  | 0.050  | -0.010 | 0.613 | 14 / 14 |
| GCP45 (3D) | 0.020/ 0.020 | 0.142   | 0.028  | 0.021  | 1.140 | 16 / 16 |
| GCP46 (3D) | 0.020/ 0.020 | -8.255  | 0.337  | 13.824 | 0.569 | 8 / 8   |
| GCP48 (3D) | 0.020/ 0.020 | -0.043  | 0.006  | 0.003  | 0.598 | 16 / 16 |
| GCP49 (3D) | 0.020/ 0.020 | -0.036  | 0.008  | 0.000  | 0.685 | 16 / 16 |
| GCP50 (3D) | 0.020/ 0.020 | -0.021  | 0.040  | 0.002  | 0.438 | 9 / 9   |
| GCP51 (3D) | 0.020/ 0.020 | -0.118  | -0.019 | 0.031  | 0.809 | 18 / 18 |
| GCP52 (3D) | 0.020/ 0.020 | -0.034  | 0.046  | 0.018  | 0.679 | 16 / 16 |
| GCP53 (3D) | 0.020/ 0.020 | -0.071  | 0.040  | 0.004  | 0.727 | 13 / 13 |
| GCP54 (3D) | 0.020/ 0.020 | -0.035  | 0.049  | -0.013 | 0.818 | 12 / 12 |
| GCP55 (3D) | 0.020/ 0.020 | -0.052  | -0.014 | 0.017  | 0.597 | 15 / 15 |
| GCP56 (3D) | 0.020/ 0.020 | -0.036  | 0.008  | -0.005 | 1.206 | 9 / 9   |
| GCP57 (3D) | 0.020/ 0.020 | 0.009   | -0.004 | 0.033  | 0.642 | 17 / 17 |
| GCP58 (3D) | 0.020/ 0.020 | 0.006   | 0.008  | 0.020  | 0.763 | 13 / 13 |
| GCP59 (3D) | 0.020/ 0.020 | -0.043  | -0.140 | -0.035 | 0.740 | 10 / 10 |
| GCP60 (3D) | 0.020/ 0.020 | 0.022   | -0.106 | 0.025  | 0.499 | 10 / 10 |
| GCP61 (3D) | 0.020/ 0.020 | 0.074   | 0.094  | -0.007 | 0.626 | 16 / 16 |
| GCP62 (3D) | 0.020/ 0.020 | 0.081   | -0.113 | 0.053  | 0.932 | 15 / 15 |
| GCP63 (3D) | 0.020/ 0.020 | -0.021  | 0.023  | -0.006 | 0.473 | 12 / 12 |
| GCP64 (3D) | 0.020/ 0.020 | -0.020  | -0.021 | -0.007 | 0.912 | 15 / 15 |
| GCP65 (3D) | 0.020/ 0.020 | -0.019  | 0.086  | -0.009 | 0.633 | 13 / 13 |
| GCP66 (3D) | 0.020/ 0.020 | 0.025   | -0.024 | -0.009 | 0.931 | 16 / 16 |
| GCP69 (3D) | 0.020/ 0.020 | 0.019   | 0.019  | -0.008 | 0.857 | 18 / 18 |
| GCP70 (3D) | 0.020/ 0.020 | -0.001  | -0.057 | 0.004  | 0.941 | 12 / 12 |
| GCP71 (3D) | 0.020/ 0.020 | 0.003   | -0.044 | -0.002 | 0.483 | 12 / 12 |
| GCP73 (3D) | 0.020/ 0.020 | -0.030  | -0.032 | 0.017  | 0.516 | 17 / 17 |
| GCP74 (3D) | 0.020/ 0.020 | 0.015   | 0.017  | -0.027 | 0.710 | 7 / 7   |
| GCP75 (3D) | 0.020/ 0.020 | -0.001  | -0.182 | 0.032  | 0.906 | 14 / 14 |

|               |              |           |          |          |       |         |
|---------------|--------------|-----------|----------|----------|-------|---------|
| GCP76 (3D)    | 0.020/ 0.020 | 0.030     | -0.040   | 0.001    | 0.938 | 22 / 22 |
| GCP77 (3D)    | 0.020/ 0.020 | 0.071     | -0.011   | 0.007    | 1.107 | 15 / 15 |
| GCP78 (3D)    | 0.020/ 0.020 | -0.009    | 0.016    | -0.308   | 1.040 | 9 / 9   |
| GCP79 (3D)    | 0.020/ 0.020 | -0.026    | -0.052   | 0.172    | 1.182 | 15 / 15 |
| GCP80 (3D)    | 0.020/ 0.020 | 0.020     | 0.009    | -0.045   | 1.046 | 12 / 12 |
| GCP81 (3D)    | 0.020/ 0.020 | 0.091     | -0.032   | -0.023   | 0.766 | 20 / 20 |
| GCP82 (3D)    | 0.020/ 0.020 | -0.035    | 0.025    | 0.005    | 0.949 | 15 / 15 |
| GCP83 (3D)    | 0.020/ 0.020 | -0.168    | 0.108    | -0.013   | 1.020 | 12 / 12 |
| GCP84 (3D)    | 0.020/ 0.020 | 0.008     | -0.167   | 0.016    | 1.120 | 19 / 19 |
| GCP85 (3D)    | 0.020/ 0.020 | 0.101     | -0.092   | -0.003   | 0.799 | 17 / 17 |
| GCP86 (3D)    | 0.020/ 0.020 | -0.017    | -0.220   | 0.011    | 0.830 | 19 / 19 |
| GCP87 (3D)    | 0.020/ 0.020 | 0.016     | 0.035    | -0.004   | 0.605 | 16 / 16 |
| GCP88 (3D)    | 0.020/ 0.020 | 0.096     | -0.059   | -0.011   | 1.412 | 13 / 13 |
| GCP89 (3D)    | 0.020/ 0.020 | -0.195    | -0.097   | 0.026    | 0.851 | 12 / 12 |
| GCP90 (3D)    | 0.020/ 0.020 | -0.034    | 0.008    | 0.027    | 1.136 | 19 / 19 |
| GCP91 (3D)    | 0.020/ 0.020 | 0.011     | 0.028    | -0.006   | 1.587 | 19 / 19 |
| GCP92 (3D)    | 0.020/ 0.020 | -0.036    | 0.029    | -0.033   | 0.971 | 9 / 9   |
| GCP93 (3D)    | 0.020/ 0.020 | 0.040     | 0.009    | 0.042    | 0.953 | 12 / 12 |
| GCP94 (3D)    | 0.020/ 0.020 | -0.035    | -0.006   | -0.004   | 0.613 | 12 / 12 |
| GCP95 (3D)    | 0.020/ 0.020 | -0.065    | -0.058   | 0.011    | 0.796 | 16 / 16 |
| GCP96 (3D)    | 0.020/ 0.020 | 0.132     | -0.072   | 0.037    | 1.212 | 12 / 12 |
| GCP97 (3D)    | 0.020/ 0.020 | -0.032    | 0.149    | 0.074    | 1.029 | 11 / 11 |
| GCP98 (3D)    | 0.020/ 0.020 | 0.056     | -0.031   | -0.011   | 0.851 | 11 / 11 |
| GCP99 (3D)    | 0.020/ 0.020 | 0.010     | -0.032   | 0.002    | 1.351 | 25 / 25 |
| GCP100 (3D)   | 0.020/ 0.020 | 0.077     | 0.126    | 0.049    | 0.866 | 8 / 8   |
| GCP101 (3D)   | 0.020/ 0.020 | -0.045    | -0.063   | 0.007    | 0.918 | 12 / 12 |
| GCP102 (3D)   | 0.020/ 0.020 | -0.080    | 0.092    | 0.026    | 1.067 | 20 / 20 |
| GCP103 (3D)   | 0.020/ 0.020 | 0.065     | -0.017   | 0.009    | 0.741 | 13 / 13 |
| GCP104 (3D)   | 0.020/ 0.020 | -0.159    | -0.135   | 0.046    | 1.259 | 17 / 17 |
| GCP105 (3D)   | 0.020/ 0.020 | 0.143     | 0.178    | 0.010    | 1.041 | 14 / 14 |
| GCP106 (3D)   | 0.020/ 0.020 | 0.199     | -0.285   | -0.135   | 1.190 | 18 / 18 |
| GCP107 (3D)   | 0.020/ 0.020 | 0.213     | 0.192    | 0.066    | 0.774 | 17 / 17 |
| GCP108 (3D)   | 0.020/ 0.020 | -0.074    | -0.006   | -0.043   | 0.957 | 15 / 15 |
| GCP109 (3D)   | 0.020/ 0.020 | -0.060    | -0.001   | -0.016   | 1.191 | 17 / 17 |
| GCP110 (3D)   | 0.020/ 0.020 | -0.024    | -0.016   | 0.015    | 0.881 | 20 / 20 |
| GCP111 (3D)   | 0.020/ 0.020 | -0.010    | -0.045   | 0.014    | 0.921 | 15 / 15 |
| GCP112 (3D)   | 0.020/ 0.020 | 0.076     | -0.053   | -0.077   | 0.891 | 15 / 15 |
| GCP113 (3D)   | 0.020/ 0.020 | 0.075     | 0.066    | -0.007   | 0.947 | 20 / 20 |
| GCP114 (3D)   | 0.020/ 0.020 | -0.130    | -0.034   | -0.016   | 1.093 | 19 / 19 |
| GCP115 (3D)   | 0.020/ 0.020 | 0.040     | 0.048    | -0.030   | 1.262 | 15 / 15 |
| GCP116 (3D)   | 0.020/ 0.020 | 0.192     | 0.025    | -0.035   | 0.791 | 16 / 16 |
| GCP117 (3D)   | 0.020/ 0.020 | -0.063    | -0.075   | -0.034   | 1.050 | 14 / 14 |
| GCP118 (3D)   | 0.020/ 0.020 | -0.046    | 0.050    | -0.023   | 0.873 | 16 / 16 |
| GCP119 (3D)   | 0.020/ 0.020 | 0.025     | -0.083   | 0.025    | 0.803 | 15 / 15 |
| GCP120 (3D)   | 0.020/ 0.020 | 0.049     | 0.063    | -0.033   | 0.983 | 14 / 14 |
| Mean [m]      |              | -0.169655 | 0.279397 | 0.100352 |       |         |
| Sigma [m]     |              | 1.713627  | 1.637502 | 1.327375 |       |         |
| RMS Error [m] |              | 1.722005  | 1.661166 | 1.331163 |       |         |

Localisation accuracy per GCP and mean errors in the three coordinate directions. The last column counts the number of calibrated images where the GCP has been automatically verified vs. manually marked.

## ? Absolute Geolocation Variance



| Mn Error [m] | Max Error [m] | Geolocation Error X[%] | Geolocation Error Y[%] | Geolocation Error Z[%] |
|--------------|---------------|------------------------|------------------------|------------------------|
| -            | -6.62         | 0.39                   | 15.69                  | 0.28                   |
| -6.62        | -5.30         | 0.64                   | 2.04                   | 0.59                   |

|               |       |           |           |           |
|---------------|-------|-----------|-----------|-----------|
| -5.30         | -3.97 | 1.01      | 2.44      | 1.31      |
| -3.97         | -2.65 | 1.79      | 3.98      | 4.64      |
| -2.65         | -1.32 | 6.96      | 7.05      | 14.33     |
| -1.32         | 0.00  | 33.21     | 7.82      | 25.91     |
| 0.00          | 1.32  | 41.50     | 11.17     | 30.19     |
| 1.32          | 2.65  | 10.87     | 17.61     | 16.08     |
| 2.65          | 3.97  | 2.06      | 15.23     | 4.73      |
| 3.97          | 5.30  | 0.84      | 7.43      | 1.10      |
| 5.30          | 6.62  | 0.37      | 4.99      | 0.46      |
| 6.62          | -     | 0.35      | 4.55      | 0.37      |
| Mean [m]      |       | -0.233407 | -2.779275 | -2.584647 |
| Sigma [m]     |       | 1.586490  | 5.389413  | 1.895428  |
| RMS Error [m] |       | 1.603568  | 6.063839  | 3.205159  |

Min Error and Max Error represent geolocation error intervals between -1.5 and 1.5 times the maximum accuracy of all the images. Columns X, Y, Z show the percentage of images with geolocation errors within the predefined error intervals. The geolocation error is the difference between the initial and computed image positions. Note that the image geolocation errors do not correspond to the accuracy of the observed 3D points.

|                  |           |           |           |
|------------------|-----------|-----------|-----------|
| Geolocation Bias | X         | Y         | Z         |
| Translation [m]  | -0.352532 | -2.494051 | -2.637247 |

Bias between image initial and computed geolocation given in output coordinate system.

? Relative Geolocation Variance

|                                   |             |             |             |
|-----------------------------------|-------------|-------------|-------------|
| Relative Geolocation Error        | Images X[%] | Images Y[%] | Images Z[%] |
| [-1.00, 1.00]                     | 89.83       | 35.16       | 87.21       |
| [-2.00, 2.00]                     | 97.25       | 71.50       | 98.54       |
| [-3.00, 3.00]                     | 99.03       | 86.51       | 99.74       |
| Mean of Geolocation Accuracy [m]  | 2.547559    | 2.547559    | 2.713834    |
| Sigma of Geolocation Accuracy [m] | 0.840136    | 0.840136    | 0.455743    |

Images X, Y, Z represent the percentage of images with a relative geolocation error in X, Y, Z.

|                                    |              |
|------------------------------------|--------------|
| Geolocation Orientational Variance | RMS [degree] |
| Omega                              | 4.321        |
| Phi                                | 6.076        |
| Kappa                              | 7.359        |

Geolocation RMS error of the orientation angles given by the difference between the initial and computed image orientation angles.

Initial Processing Details

System Information

|                  |                                                                                                                |
|------------------|----------------------------------------------------------------------------------------------------------------|
| Hardware         | CPU: Intel(R) Core(TM) i7-3930K CPU @ 3.20GHz<br>RAM: 64GB<br>GPU: NVIDIA Quadro K4000 (Driver: 10.18.13.5442) |
| Operating System | Windows 8, 64-bit                                                                                              |

Coordinate Systems

|                                              |                      |
|----------------------------------------------|----------------------|
| Image Coordinate System                      | WGS84                |
| Ground Control Point (GCP) Coordinate System | WGS84                |
| Output Coordinate System                     | WGS84 / UTM zone 36S |

|                                |                                                                                                                                     |
|--------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| Detected Template              |  half dsm 100*                                     |
| Keypoints Image Scale          | Custom, Image Scale: 0.5                                                                                                            |
| Advanced: Matching Image Pairs | Aerial Grid or Corridor                                                                                                             |
| Advanced: Matching Strategy    | Use Geometrically Verified Matching: no                                                                                             |
| Advanced: Keypoint Extraction  | Targeted Number of Keypoints: Automatic                                                                                             |
| Advanced: Calibration          | Calibration Method: Standard<br>Internal Parameters Optimization: All<br>External Parameters Optimization: All<br>Rematch: Auto, no |

Agri-Sense International

## **Appendix 2**

### Image Processing Report Description



**Average Ground Sampling Distance;** this parameter defines the average pixel size of the map to be produced, in this case the average pixel size of the final map was 7.47cm.

**Image Coordinate System,** is a parameter which describes what coordinate system was used by the UAV while it was collecting images during survey. The UAV uses the standard and internationally accepted World Geodetic Standard 1984 geographic datum (WGS84) to position the photographs it takes.

**Output Coordinate System,** is the coordinate system in which the final map and Digital Surface Model (DSM) will be exported from the program. In this instance the outputs were modelled on the Universal Transverse Mercator Coordinate system centred on 30N Zone, while being based on the WGS84 Datum.

**Images – Keypoints per Image;** this parameter describes the average number of definable keypoints in each image, that are able to be compared to keypoints in surrounding images. This process is done so that matching keypoints in images may be found and the program may generate the map to a high degree of accuracy. A value of 10000 or more is required

**Dataset – images Calibration;** this parameter defines the percentage of images processed that are enabled. Above 90% indicates good calibration and that the images are all of good quality. Where the image matching is less than 90%, some of the images were too blurry to process and so have been disabled so that they will not affect the final orthomosaic image or DSM quality. The Matching Quality Parameter describes the quality of the remaining enabled image.

**Camera Optimisation;** For this parameter any value over 5% suggests that there were problems with the camera while it was taking photos, as the focal length for each image is far from optimal. For values less than 5% the camera lens functions were within optimal levels.

**Matching;** this parameter describes how many keypoints could, on average, be matched for each of the enabled and calibrated images. Any value greater than 1000 shows that strong matching and that the images themselves are of sufficiently high quality to generate an accurate map.

**Georeferencing;** This parameter defines whether or not the average error in the map is less than the Ground Sampling Distance, so the results show the average error in the X, Y and Z directions. The value displayed as the mean error is the difference between the images and the ground control points (GCP) that was corrected during processing. A lower value shows better matching between the Images and the GCP's. If there were an error or some inaccuracy with the images or GCP's then the processing report would show a red cross instead of a green tick with this parameter.

## **Appendix 3**

### List of Temporary GCP Locations

| GCP_Name | LONGITUDE | LATITUDE  | ELEVATION | ATTR_1      |
|----------|-----------|-----------|-----------|-------------|
| B1       | 32.20649  | -26.27667 | 94        | base1       |
| B2       | 32.20649  | -26.27679 | 93.992    | base1d2     |
| B3       | 32.24472  | -26.25006 | 116.828   | base1-d3    |
| B4       | 32.24099  | -26.24206 | 124.238   | base1-d4    |
| B5       | 32.24469  | -26.25008 | 116.976   | base1-d5    |
| B6       | 32.19903  | -26.29309 | 95.373    | base1-d6    |
| GCP1     | 32.20047  | -26.28196 | 92.935    | maed1-gcp1  |
| GCP2     | 32.19805  | -26.29161 | 96.007    | maed1-gcp2  |
| GCP3     | 32.2105   | -26.30226 | 90.906    | maed1-gcp3  |
| GCP4     | 32.2086   | -26.29438 | 88.83     | maed1-gcp4  |
| GCP5     | 32.22105  | -26.30857 | 86.324    | maed1-gcp5  |
| GCP6     | 32.22969  | -26.31055 | 81.196    | maed1-gcp6  |
| GCP7     | 32.23998  | -26.30841 | 73.577    | maed1-gcp7  |
| GCP8     | 32.23114  | -26.30532 | 80.228    | maed1-gcp8  |
| GCP9     | 32.2272   | -26.30011 | 82.932    | maed1-gcp9  |
| GCP10    | 32.1932   | -26.23119 | 99.513    | maed1-gcp10 |
| GCP11    | 32.20102  | -26.22332 | 90.286    | maed1-gcp11 |
| GCP12    | 32.20257  | -26.22742 | 99.129    | maed1-gcp12 |
| GCP13    | 32.20291  | -26.23307 | 103.766   | maed1-gcp13 |
| GCP14    | 32.20381  | -26.24158 | 116.946   | maed1-gcp14 |
| GCP15    | 32.19422  | -26.23953 | 108.756   | maed1-gcp15 |
| GCP16    | 32.19692  | -26.24777 | 118.406   | maed1-gcp16 |
| GCP17    | 32.20225  | -26.25142 | 116.806   | maed1-gcp17 |
| GCP18    | 32.20231  | -26.26191 | 108.973   | maed1-gcp18 |
| GCP19    | 32.27446  | -26.26381 | 85.252    | maed1-gcp19 |
| GCP20    | 32.20657  | -26.27681 | 93.852    | maed2-gcp20 |
| GCP21    | 32.1809   | -26.27791 | 99.5      | maed2-gcp21 |
| GCP22    | 32.19067  | -26.26511 | 101.526   | maed2-gcp22 |
| GCP23    | 32.18557  | -26.2554  | 108.843   | maed2-gcp23 |
| GCP24    | 32.17581  | -26.22241 | 86.282    | maed2-gcp24 |
| GCP25    | 32.18407  | -26.22613 | 81.297    | maed2-gcp25 |
| GCP26    | 32.19467  | -26.22248 | 81.977    | maed2-gcp26 |
| GCP27    | 32.19467  | -26.22248 | 81.971    | maed2-gcp27 |
| GCP28    | 32.19467  | -26.22248 | 81.966    | maed2-gcp28 |
| GCP29    | 32.21071  | -26.25118 | 108.116   | maed2-gcp29 |
| GCP30    | 32.21356  | -26.25722 | 100.97    | maed2-gcp30 |
| GCP31    | 32.21356  | -26.25722 | 100.964   | maed2-gcp31 |
| GCP32    | 32.22002  | -26.2515  | 105.294   | maed2-gcp32 |
| GCP33    | 32.21634  | -26.272   | 93.691    | maed2-gcp33 |
| GCP34    | 32.21637  | -26.27201 | 93.704    | maed2-gcp34 |
| GCP35    | 32.2236   | -26.26355 | 94.391    | maed2-gcp35 |
| GCP36    | 32.22526  | -26.25598 | 102.143   | maed2-gcp36 |
| GCP37    | 32.24471  | -26.25004 | 116.802   | maed3-gcp45 |
| GCP38    | 32.24292  | -26.25432 | 130.869   | maed3-gcp46 |
| GCP39    | 32.23572  | -26.26742 | 95.169    | maed3-gcp47 |
| GCP40    | 32.23178  | -26.27565 | 88.079    | maed3-gcp48 |
| GCP41    | 32.23358  | -26.2796  | 86.028    | maed3-gcp49 |
| GCP42    | 32.23523  | -26.28718 | 82.796    | maed3-gcp50 |
| GCP43    | 32.23888  | -26.29251 | 82.478    | maed3-gcp51 |

|       |          |           |         |             |
|-------|----------|-----------|---------|-------------|
| GCP44 | 32.2501  | -26.29236 | 81.244  | maed3-gcp52 |
| GCP45 | 32.25978 | -26.29101 | 72.131  | maed3-gcp53 |
| GCP46 | 32.26509 | -26.29036 | 81.292  | maed3-gcp54 |
| GCP47 | 32.2633  | -26.29069 | 70.022  | maed3-gcp54 |
| GCP48 | 32.26843 | -26.28998 | 69.985  | maed3-gcp55 |
| GCP49 | 32.26843 | -26.28998 | 69.978  | maed3-gcp56 |
| GCP50 | 32.27582 | -26.28927 | 76.554  | maed3-gcp57 |
| GCP51 | 32.25229 | -26.28542 | 82.386  | maed3-gcp58 |
| GCP52 | 32.24531 | -26.28638 | 91.239  | maed3-gcp59 |
| GCP53 | 32.24472 | -26.27772 | 92.697  | maed3-gcp60 |
| GCP54 | 32.24412 | -26.26926 | 96.431  | maed3-gcp61 |
| GCP55 | 32.24432 | -26.26582 | 101.356 | maed3-gcp62 |
| GCP56 | 32.23644 | -26.25072 | 109.805 | maed3-gcp63 |
| GCP57 | 32.28937 | -26.21584 | 61.719  | maed3-gcp64 |
| GCP58 | 32.30515 | -26.21975 | 74.788  | maed3-gcp65 |
| GCP59 | 32.24885 | -26.25249 | 103.605 | maed4-gcp70 |
| GCP60 | 32.25591 | -26.24977 | 108.513 | maed4-gcp71 |
| GCP61 | 32.26386 | -26.25374 | 81.673  | maed4-gcp72 |
| GCP62 | 32.27103 | -26.25508 | 81.575  | maed4-gcp73 |
| GCP63 | 32.27762 | -26.25264 | 84.673  | maed4-gcp74 |
| GCP64 | 32.28568 | -26.24975 | 82.136  | maed4-gcp75 |
| GCP65 | 32.2933  | -26.24654 | 84.914  | maed4-gcp76 |
| GCP66 | 32.30044 | -26.24397 | 79.004  | maed4-gcp77 |
| GCP67 | 32.30775 | -26.24271 | 71.094  | maed4-gcp78 |
| GCP68 | 32.30774 | -26.24261 | 71.039  | maed4-gcp79 |
| GCP69 | 32.30713 | -26.24134 | 70.573  | maed4-gcp80 |
| GCP70 | 32.29946 | -26.23741 | 79.452  | maed4-gcp81 |
| GCP71 | 32.29946 | -26.22978 | 76.518  | maed4-gcp82 |
| GCP72 | 32.29946 | -26.22978 | 76.522  | maed4-gcp83 |
| GCP73 | 32.26165 | -26.23576 | 100.298 | maed4-gcp84 |
| GCP74 | 32.26633 | -26.2347  | 158.185 | maed4-gcp85 |
| GCP75 | 32.27375 | -26.23327 | 85.107  | maed4-gcp86 |
| GCP76 | 32.26789 | -26.24351 | 78.056  | maed4-gcp87 |
| GCP77 | 32.27343 | -26.22639 | 77.747  | maed4-gcp88 |
| GCP78 | 32.27    | -26.22037 | 71.393  | maed4-gcp89 |
| GCP79 | 32.27    | -26.22037 | 71.398  | maed4-gcp90 |
| GCP80 | 32.26231 | -26.22185 | 83.73   | maed4-gcp91 |
| GCP81 | 32.28439 | -26.22538 | 63.015  | maed4-gcp92 |
| GCP82 | 32.28157 | -26.23933 | 74.963  | maed4-gcp93 |
| GCP83 | 32.2886  | -26.23605 | 76.918  | maed4-gcp94 |
| GCP84 | 32.25692 | -26.27657 | 79.458  | maed5-gcp10 |
| GCP85 | 32.25719 | -26.27999 | 75.819  | maed5-gcp11 |
| GCP86 | 32.25738 | -26.26917 | 78.762  | maed5-gcp12 |
| GCP87 | 32.26193 | -26.26969 | 76.016  | maed5-gcp13 |
| GCP88 | 32.28616 | -26.25475 | 87.442  | maed5-gcp14 |
| GCP89 | 32.28613 | -26.25991 | 91.753  | maed5-gcp15 |
| GCP90 | 32.28257 | -26.26344 | 92.022  | maed5-gcp16 |
| GCP91 | 32.28257 | -26.26344 | 92.022  | maed5-gcp17 |
| GCP92 | 32.28439 | -26.26884 | 93.256  | maed5-gcp18 |
| GCP93 | 32.3033  | -26.25149 | 76.471  | maed5-gcp19 |

|           |          |           |        |                 |
|-----------|----------|-----------|--------|-----------------|
| GCP94     | 32.30848 | -26.25119 | 69.563 | maed5-gcp20     |
| GCP95     | 32.30694 | -26.26199 | 72.799 | maed5-gcp21     |
| GCP96     | 32.30051 | -26.26254 | 80.035 | maed5-gcp22     |
| GCP97     | 32.29624 | -26.26419 | 83.912 | maed5-gcp23     |
| GCP98     | 32.29056 | -26.26627 | 87.602 | maed5-gcp24     |
| GCP99     | 32.28048 | -26.27024 | 91.704 | maed5-gcp25     |
| GCP100    | 32.28909 | -26.27169 | 90.018 | maed5-gcp26     |
| GCP101    | 32.28821 | -26.27688 | 89.383 | maed5-gcp27     |
| GCP102    | 32.2746  | -26.26389 | 85.698 | maed5-gcp3      |
| GCP103    | 32.27233 | -26.27309 | 83.332 | maed5-gcp4      |
| GCP104    | 32.27184 | -26.27941 | 79.377 | maed5-gcp5      |
| GCP105    | 32.27127 | -26.28285 | 76.355 | maed5-gcp6      |
| GCP106    | 32.27248 | -26.28734 | 75.227 | maed5-gcp7      |
| GCP107    | 32.26662 | -26.27378 | 75.325 | maed5-gcp8      |
| GCP108    | 32.26201 | -26.27321 | 74.496 | maed5-gcp9      |
| GCP109    | 32.24563 | -26.32118 | 72.172 | maed6-gcp1      |
| GCP110    | 32.28206 | -26.28029 | 86.046 | maed6-gcp10     |
| GCP111    | 32.30716 | -26.27519 | 72.383 | maed6-gcp11     |
| GCP112    | 32.27415 | -26.30262 | 69.086 | maed6-gcp12     |
| GCP113    | 32.25269 | -26.32072 | 69.86  | maed6-gcp2      |
| GCP114    | 32.25847 | -26.31847 | 67.344 | maed6-gcp3      |
| GCP115    | 32.26799 | -26.31997 | 64.797 | maed6-gcp4      |
| GCP116    | 32.25895 | -26.30703 | 68.381 | maed6-gcp5      |
| GCP117    | 32.24504 | -26.30954 | 86.666 | maed6-gcp6      |
| GCP118    | 32.25127 | -26.3023  | 76.868 | maed6-gcp7      |
| GCP119    | 32.29539 | -26.27781 | 83.725 | maed6-gcp8      |
| GCP120    | 32.29049 | -26.27872 | 86.207 | maed6-gcp9      |
| BenchMarl | 32.2823  | -26.28028 | 86.561 | maed6-bench1-43 |
| Benchmarl | 32.2886  | -26.27938 | 87.741 | maed6-bench2    |

**Appendix 4**  
Trimble R4 GNSS GPS  
Calibration Report



| Project file data |                                                                                               | Coordinate System |          |
|-------------------|-----------------------------------------------------------------------------------------------|-------------------|----------|
| Name:             | C:\Users\Agri-sense\Documents\1_AgrisenseData\MAE61\Trimble\TrimbleData\MAE61_D1\mae61_d1.vce | Name:             | Default  |
| Size:             | 63 KB                                                                                         | Datum:            | WGS 1984 |
| Modified:         | 2016-08-10 03:41:57 PM (UTC:2)                                                                | Zone:             | Default  |
| Time zone:        | South Africa Standard Time                                                                    | Geoid:            |          |
| Reference number: |                                                                                               | Vertical datum:   |          |
| Description:      |                                                                                               |                   |          |
| Comment 1:        |                                                                                               |                   |          |
| Comment 2:        |                                                                                               |                   |          |
| Comment 3:        |                                                                                               |                   |          |

#### Additional Coordinate System Details

| Local Site Settings |         |                        |       |
|---------------------|---------|------------------------|-------|
| Project latitude:   | ?       | Ground scale factor:   | 1     |
| Project longitude:  | ?       | False northing offset: | 0.000 |
| Project height:     | 100.000 | False easting offset:  | 0.000 |

### Baseline Processing Report

#### Processing Summary

| Observation       | From  | To          | Solution Type | H. Prec. (Meter) | V. Prec. (Meter) | Geodetic Az. | Ellipsoid Dist. (Meter) | ΔHeight (Meter) |
|-------------------|-------|-------------|---------------|------------------|------------------|--------------|-------------------------|-----------------|
| maed1-gcp1 (B1)   | base1 | maed1-gcp1  | Fixed         | 0.008            | 0.016            | 45°40'59"    | 839.577                 | -1.065          |
| maed1-gcp2 (B2)   | base1 | maed1-gcp2  | Fixed         | 0.011            | 0.020            | 26°58'53"    | 1857.923                | 2.007           |
| maed1-gcp3 (B3)   | base1 | maed1-gcp3  | Fixed         | 0.013            | 0.025            | 351°57'56"   | 2864.137                | -3.094          |
| maed1-gcp4 (B4)   | base1 | maed1-gcp4  | Fixed         | 0.012            | 0.022            | 353°51'46"   | 1974.362                | -5.170          |
| maed1-gcp5 (B5)   | base1 | maed1-gcp5  | Fixed         | 0.016            | 0.026            | 337°38'11"   | 3822.449                | -7.676          |
| maed1-gcp6 (B6)   | base1 | maed1-gcp6  | Fixed         | 0.013            | 0.019            | 328°19'11"   | 4411.853                | -12.804         |
| maed1-gcp7 (B7)   | base1 | maed1-gcp7  | Fixed         | 0.015            | 0.023            | 316°26'18"   | 4853.351                | -20.423         |
| maed1-gcp8 (B8)   | base1 | maed1-gcp8  | Fixed         | 0.014            | 0.022            | 322°12'30"   | 4016.890                | -13.772         |
| maed1-gcp9 (B9)   | base1 | maed1-gcp9  | Fixed         | 0.013            | 0.022            | 321°28'19"   | 3320.471                | -11.068         |
| maed1-gcp10 (B10) | base1 | maed1-gcp10 | Fixed         | 0.011            | 0.023            | 165°14'22"   | 5210.085                | 5.513           |
| maed1-gcp11 (B11) | base1 | maed1-gcp11 | Fixed         | 0.013            | 0.025            | 174°43'04"   | 5935.550                | -3.714          |
| maed1-gcp12 (B12) | base1 | maed1-gcp12 | Fixed         | 0.007            | 0.013            | 175°53'38"   | 5470.685                | 5.129           |
| maed1-gcp13 (B13) | base1 | maed1-gcp13 | Fixed         | 0.020            | 0.037            | 175°45'41"   | 4843.052                | 9.766           |
| maed1-gcp14 (B14) | base1 | maed1-gcp14 | Fixed         | 0.009            | 0.016            | 176°03'59"   | 3896.098                | 22.946          |
| maed1-gcp15 (B15) | base1 | maed1-gcp15 | Fixed         | 0.015            | 0.028            | 163°24'55"   | 4293.528                | 14.756          |
| maed1-gcp16 (B16) | base1 | maed1-gcp16 | Fixed         | 0.013            | 0.023            | 163°22'35"   | 3340.661                | 24.406          |

|                   |       |             |       |       |       |            |          |        |
|-------------------|-------|-------------|-------|-------|-------|------------|----------|--------|
| maed1-gcp17 (B17) | base1 | maed1-gcp17 | Fixed | 0.012 | 0.020 | 171°23'26" | 2829.180 | 22.806 |
| maed1-gcp18 (B18) | base1 | maed1-gcp18 | Fixed | 0.011 | 0.016 | 165°41'19" | 1686.883 | 14.973 |

### Acceptance Summary

| Processed | Passed | Flag |  | Fail |  |
|-----------|--------|------|-------------------------------------------------------------------------------------|------|-------------------------------------------------------------------------------------|
| 18        | 18     | 0    |                                                                                     | 0    |                                                                                     |

### base1 (11:46:33 AM-04:25:32 PM) (S1)

|                               |                                         |
|-------------------------------|-----------------------------------------|
| <b>Baseline observation:</b>  | maed1-gcp1 (B1)                         |
| <b>Processed:</b>             | 2016-08-10 03:47:16 PM                  |
| <b>Solution type:</b>         | Fixed                                   |
| <b>Frequency used:</b>        | Dual Frequency (L1, L2)                 |
| <b>Horizontal precision:</b>  | 0.008 m                                 |
| <b>Vertical precision:</b>    | 0.016 m                                 |
| <b>RMS:</b>                   | 0.008 m                                 |
| <b>Maximum PDOP:</b>          | 1.573                                   |
| <b>Ephemeris used:</b>        | Broadcast                               |
| <b>Antenna model:</b>         | NGS Absolute                            |
| <b>Processing start time:</b> | 2016-08-04 12:00:36 PM (Local: UTC+2hr) |
| <b>Processing stop time:</b>  | 2016-08-04 12:01:03 PM (Local: UTC+2hr) |
| <b>Processing duration:</b>   | 00:00:27                                |
| <b>Processing interval:</b>   | 1 second                                |

### Vector Components (Mark to Mark)

|           |               |           |                  |           |                  |
|-----------|---------------|-----------|------------------|-----------|------------------|
| From:     | base1         |           |                  |           |                  |
| Grid      |               | Local     |                  | Global    |                  |
| Easting   | 79259.135 m   | Latitude  | S26°16'36.00000" | Latitude  | S26°16'36.00000" |
| Northing  | 2907729.492 m | Longitude | E32°12'23.35720" | Longitude | E32°12'23.35720" |
| Elevation | 94.000 m      | Height    | 94.000 m         | Height    | 94.000 m         |

|           |               |           |                  |           |                  |
|-----------|---------------|-----------|------------------|-----------|------------------|
| To:       | maed1-gcp1    |           |                  |           |                  |
| Grid      |               | Local     |                  | Global    |                  |
| Easting   | 79856.278 m   | Latitude  | S26°16'55.05851" | Latitude  | S26°16'55.05851" |
| Northing  | 2908319.763 m | Longitude | E32°12'01.70531" | Longitude | E32°12'01.70531" |
| Elevation | 92.935 m      | Height    | 92.935 m         | Height    | 92.935 m         |

|            |           |                 |           |    |            |
|------------|-----------|-----------------|-----------|----|------------|
| Vector     |           |                 |           |    |            |
| ΔEasting   | 597.143 m | NS Fwd Azimuth  | 45°40'59" | ΔX | 99.595 m   |
| ΔNorthing  | 590.270 m | Ellipsoid Dist. | 839.577 m | ΔY | -647.217 m |
| ΔElevation | -1.065 m  | ΔHeight         | -1.065 m  | ΔZ | -525.453 m |

### Standard Errors

|                |         |                   |          |      |         |
|----------------|---------|-------------------|----------|------|---------|
| Vector errors: |         |                   |          |      |         |
| σ ΔEasting     | 0.003 m | σ NS fwd Azimuth  | 0°00'01" | σ ΔX | 0.007 m |
| σ ΔNorthing    | 0.003 m | σ Ellipsoid Dist. | 0.003 m  | σ ΔY | 0.005 m |
| σ ΔElevation   | 0.008 m | σ ΔHeight         | 0.008 m  | σ ΔZ | 0.004 m |

### Aposteriori Covariance Matrix (Meter<sup>2</sup>)

|   |               |               |              |
|---|---------------|---------------|--------------|
|   | X             | Y             | Z            |
| X | 0.0000470468  |               |              |
| Y | 0.0000197759  | 0.0000212103  |              |
| Z | -0.0000146438 | -0.0000085550 | 0.0000155685 |

## Occupations

|                                   | From                                                                                                               | To                                                                                                                 |
|-----------------------------------|--------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|
| <b>Point ID:</b>                  | base1                                                                                                              | maed1-gcp1                                                                                                         |
| <b>Data file:</b>                 | C:\Users\Agri-sense\Documents<br>\1_AgrisenseData\MAE61\Trimble<br>\TrimbleData<br>\MAE61_D1\mae61_d1\11272171.T02 | C:\Users\Agri-sense\Documents<br>\1_AgrisenseData\MAE61\Trimble<br>\TrimbleData<br>\MAE61_D1\mae61_d1\58582170.T02 |
| <b>Receiver type:</b>             | R4-3                                                                                                               | R4-3                                                                                                               |
| <b>Receiver serial number:</b>    | 5544441127                                                                                                         | 5537435858                                                                                                         |
| <b>Antenna type:</b>              | R4-3 Internal                                                                                                      | R4-3 Internal                                                                                                      |
| <b>Antenna serial number:</b>     | 54444127                                                                                                           | 37435858                                                                                                           |
| <b>Antenna height (measured):</b> | 1.770 m                                                                                                            | 2.000 m                                                                                                            |
| <b>Antenna method:</b>            | Bottom of antenna mount                                                                                            | Bottom of antenna mount                                                                                            |

| Project file data |                                                                                               | Coordinate System |          |
|-------------------|-----------------------------------------------------------------------------------------------|-------------------|----------|
| Name:             | C:\Users\Agri-sense\Documents\1_AgrisenseData\MAE61\Trimble\TrimbleData\mae61_d2\mae61_d2.vce | Name:             | Default  |
| Size:             | 81 KB                                                                                         | Datum:            | WGS 1984 |
| Modified:         | 2016-08-10 04:02:56 PM (UTC:2)                                                                | Zone:             | Default  |
| Time zone:        | South Africa Standard Time                                                                    | Geoid:            |          |
| Reference number: |                                                                                               | Vertical datum:   |          |
| Description:      |                                                                                               |                   |          |
| Comment 1:        |                                                                                               |                   |          |
| Comment 2:        |                                                                                               |                   |          |
| Comment 3:        |                                                                                               |                   |          |

#### Additional Coordinate System Details

| Local Site Settings |         |                        |       |
|---------------------|---------|------------------------|-------|
| Project latitude:   | ?       | Ground scale factor:   | 1     |
| Project longitude:  | ?       | False northing offset: | 0.000 |
| Project height:     | 100.000 | False easting offset:  | 0.000 |

### Baseline Processing Report

#### Processing Summary

| Observation       | From    | To          | Solution Type | H. Prec. (Meter) | V. Prec. (Meter) | Geodetic Az. | Ellipsoid Dist. (Meter) | ΔHeight (Meter) |
|-------------------|---------|-------------|---------------|------------------|------------------|--------------|-------------------------|-----------------|
| maed2-gcp20 (B1)  | base1d2 | maed2-gcp20 | Fixed         | 0.003            | 0.006            | 285°33'23"   | 8.226                   | -0.140          |
| maed2-gcp21 (B2)  | base1d2 | maed2-gcp21 | Fixed         | 0.012            | 0.027            | 87°12'36"    | 2558.916                | 5.508           |
| maed2-gcp22 (B3)  | base1d2 | maed2-gcp22 | Fixed         | 0.011            | 0.029            | 129°17'57"   | 2042.464                | 7.534           |
| maed2-gcp23 (B4)  | base1d2 | maed2-gcp23 | Fixed         | 0.010            | 0.024            | 138°35'17"   | 3159.440                | 14.851          |
| maed2-gcp24 (B5)  | base1d2 | maed2-gcp24 | Fixed         | 0.012            | 0.028            | 153°01'57"   | 6759.718                | -7.710          |
| maed2-gcp25 (B6)  | base1d2 | maed2-gcp25 | Fixed         | 0.012            | 0.026            | 158°14'39"   | 6043.260                | -12.695         |
| maed2-gcp26 (B7)  | base1d2 | maed2-gcp26 | Fixed         | 0.011            | 0.021            | 168°53'53"   | 6131.661                | -12.015         |
| maed2-gcp27 (B8)  | base1d2 | maed2-gcp27 | Fixed         | 0.011            | 0.021            | 168°53'52"   | 6131.698                | -12.021         |
| maed2-gcp28 (B9)  | base1d2 | maed2-gcp28 | Fixed         | 0.011            | 0.021            | 168°53'52"   | 6131.694                | -12.026         |
| maed2-gcp29 (B11) | base1d2 | maed2-gcp29 | Fixed         | 0.010            | 0.014            | 188°27'28"   | 2868.842                | 14.124          |
| maed2-gcp30 (B12) | base1d2 | maed2-gcp30 | Fixed         | 0.012            | 0.019            | 198°03'33"   | 2280.531                | 6.978           |
| maed2-gcp31 (B13) | base1d2 | maed2-gcp31 | Fixed         | 0.012            | 0.019            | 198°03'33"   | 2280.556                | 6.972           |
| maed2-gcp32 (B14) | base1d2 | maed2-gcp32 | Fixed         | 0.011            | 0.021            | 205°45'40"   | 3110.209                | 11.302          |
| maed2-gcp33 (B15) | base1d2 | maed2-gcp33 | Fixed         | 0.013            | 0.018            | 241°41'26"   | 1118.222                | -0.301          |
| maed2-gcp34 (B16) | base1d2 | maed2-gcp34 | Fixed         | 0.011            | 0.015            | 241°48'55"   | 1119.970                | -0.288          |
| maed2-gcp35 (B17) | base1d2 | maed2-gcp35 | Fixed         | 0.014            | 0.026            | 229°21'46"   | 2252.196                | 0.399           |

|                   |         |             |       |       |       |            |          |       |
|-------------------|---------|-------------|-------|-------|-------|------------|----------|-------|
| maed2-gcp36 (B18) | base1d2 | maed2-gcp36 | Fixed | 0.016 | 0.033 | 219°07'00" | 2971.856 | 8.151 |
|-------------------|---------|-------------|-------|-------|-------|------------|----------|-------|

### Acceptance Summary

| Processed | Passed | Flag | Fail |
|-----------|--------|------|------|
| 17        | 17     | 0    | 0    |

### base1d2 (08:51:52 AM-10:42:03 AM) (S1)

|                        |                                         |
|------------------------|-----------------------------------------|
| Baseline observation:  | maed2-gcp20 (B1)                        |
| Processed:             | 2016-08-10 03:55:27 PM                  |
| Solution type:         | Fixed                                   |
| Frequency used:        | Dual Frequency (L1, L2)                 |
| Horizontal precision:  | 0.003 m                                 |
| Vertical precision:    | 0.006 m                                 |
| RMS:                   | 0.008 m                                 |
| Maximum PDOP:          | 1.659                                   |
| Ephemeris used:        | Broadcast                               |
| Antenna model:         | NGS Absolute                            |
| Processing start time: | 2016-08-05 08:52:20 AM (Local: UTC+2hr) |
| Processing stop time:  | 2016-08-05 09:00:23 AM (Local: UTC+2hr) |
| Processing duration:   | 00:08:03                                |
| Processing interval:   | 1 second                                |



### Vector Components (Mark to Mark)

|                  |               |                  |                  |                  |                  |
|------------------|---------------|------------------|------------------|------------------|------------------|
| From:            | base1d2       |                  |                  |                  |                  |
| <b>Grid</b>      |               | <b>Local</b>     |                  | <b>Global</b>    |                  |
| <b>Easting</b>   | 79259.047 m   | <b>Latitude</b>  | S26°16'36.43628" | <b>Latitude</b>  | S26°16'36.43628" |
| <b>Northing</b>  | 2907742.920 m | <b>Longitude</b> | E32°12'23.35739" | <b>Longitude</b> | E32°12'23.35739" |
| <b>Elevation</b> | 93.992 m      | <b>Height</b>    | 93.992 m         | <b>Height</b>    | 93.992 m         |

|                  |               |                  |                  |                  |                  |
|------------------|---------------|------------------|------------------|------------------|------------------|
| To:              | maed2-gcp20   |                  |                  |                  |                  |
| <b>Grid</b>      |               | <b>Local</b>     |                  | <b>Global</b>    |                  |
| <b>Easting</b>   | 79251.108 m   | <b>Latitude</b>  | S26°16'36.50797" | <b>Latitude</b>  | S26°16'36.50797" |
| <b>Northing</b>  | 2907745.078 m | <b>Longitude</b> | E32°12'23.64303" | <b>Longitude</b> | E32°12'23.64303" |
| <b>Elevation</b> | 93.852 m      | <b>Height</b>    | 93.852 m         | <b>Height</b>    | 93.852 m         |

|                   |          |                        |            |           |          |
|-------------------|----------|------------------------|------------|-----------|----------|
| <b>Vector</b>     |          |                        |            |           |          |
| <b>ΔEasting</b>   | -7.939 m | <b>NS Fwd Azimuth</b>  | 285°33'23" | <b>ΔX</b> | -5.156 m |
| <b>ΔNorthing</b>  | 2.158 m  | <b>Ellipsoid Dist.</b> | 8.226 m    | <b>ΔY</b> | 6.118 m  |
| <b>ΔElevation</b> | -0.140 m | <b>ΔHeight</b>         | -0.140 m   | <b>ΔZ</b> | -1.916 m |

### Standard Errors

|                       |         |                          |          |             |         |
|-----------------------|---------|--------------------------|----------|-------------|---------|
| <b>Vector errors:</b> |         |                          |          |             |         |
| <b>σ ΔEasting</b>     | 0.001 m | <b>σ NS fwd Azimuth</b>  | 0°00'30" | <b>σ ΔX</b> | 0.002 m |
| <b>σ ΔNorthing</b>    | 0.001 m | <b>σ Ellipsoid Dist.</b> | 0.001 m  | <b>σ ΔY</b> | 0.002 m |
| <b>σ ΔElevation</b>   | 0.003 m | <b>σ ΔHeight</b>         | 0.003 m  | <b>σ ΔZ</b> | 0.001 m |

### Aposteriori Covariance Matrix (Meter<sup>2</sup>)

|          |               |               |              |
|----------|---------------|---------------|--------------|
|          | <b>X</b>      | <b>Y</b>      | <b>Z</b>     |
| <b>X</b> | 0.0000061379  |               |              |
| <b>Y</b> | 0.0000030978  | 0.0000033460  |              |
| <b>Z</b> | -0.0000018971 | -0.0000012622 | 0.0000020167 |

## Occupations

|                                   | From                                                                                                               | To                                                                                                                 |
|-----------------------------------|--------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|
| <b>Point ID:</b>                  | base1d2                                                                                                            | maed2-gcp20                                                                                                        |
| <b>Data file:</b>                 | C:\Users\Agri-sense\Documents<br>\1_AgrisenseData\MAE61\Trimble<br>\TrimbleData<br>\mae61_d2\mae61_d2\11272180.T02 | C:\Users\Agri-sense\Documents<br>\1_AgrisenseData\MAE61\Trimble<br>\TrimbleData<br>\mae61_d2\mae61_d2\58582180.T02 |
| <b>Receiver type:</b>             | R4-3                                                                                                               | R4-3                                                                                                               |
| <b>Receiver serial number:</b>    | 5544441127                                                                                                         | 5537435858                                                                                                         |
| <b>Antenna type:</b>              | R4-3 Internal                                                                                                      | R4-3 Internal                                                                                                      |
| <b>Antenna serial number:</b>     | 54444127                                                                                                           | 37435858                                                                                                           |
| <b>Antenna height (measured):</b> | 1.820 m                                                                                                            | 2.000 m                                                                                                            |
| <b>Antenna method:</b>            | Bottom of antenna mount                                                                                            | Bottom of antenna mount                                                                                            |

| Project file data |                                                                                               | Coordinate System |          |
|-------------------|-----------------------------------------------------------------------------------------------|-------------------|----------|
| Name:             | C:\Users\Agri-sense\Documents\1_AgrisenseData\MAE61\Trimble\TrimbleData\mae61_d3\mae61_d3.vce | Name:             | Default  |
| Size:             | 77 KB                                                                                         | Datum:            | WGS 1984 |
| Modified:         | 2016-08-10 04:37:24 PM (UTC:2)                                                                | Zone:             | Default  |
| Time zone:        | South Africa Standard Time                                                                    | Geoid:            |          |
| Reference number: |                                                                                               | Vertical datum:   |          |
| Description:      |                                                                                               |                   |          |
| Comment 1:        |                                                                                               |                   |          |
| Comment 2:        |                                                                                               |                   |          |
| Comment 3:        |                                                                                               |                   |          |

#### Additional Coordinate System Details

| Local Site Settings |         |                        |       |
|---------------------|---------|------------------------|-------|
| Project latitude:   | ?       | Ground scale factor:   | 1     |
| Project longitude:  | ?       | False northing offset: | 0.000 |
| Project height:     | 100.000 | False easting offset:  | 0.000 |

### Baseline Processing Report

#### Processing Summary

| Observation       | From     | To          | Solution Type | H. Prec. (Meter) | V. Prec. (Meter) | Geodetic Az. | Ellipsoid Dist. (Meter) | ΔHeight (Meter) |
|-------------------|----------|-------------|---------------|------------------|------------------|--------------|-------------------------|-----------------|
| maed3-gcp45 (B1)  | base1-d3 | maed3-gcp45 | Fixed         | 0.005            | 0.010            | 145°26'31"   | 2.635                   | -0.026          |
| maed3-gcp46 (B2)  | base1-d3 | maed3-gcp46 | Fixed         | 0.007            | 0.017            | 20°55'22"    | 505.313                 | 14.041          |
| maed3-gcp47 (B3)  | base1-d3 | maed3-gcp47 | Fixed         | 0.013            | 0.030            | 25°03'26"    | 2123.222                | -21.659         |
| maed3-gcp48 (B4)  | base1-d3 | maed3-gcp48 | Fixed         | 0.011            | 0.025            | 24°30'32"    | 3115.176                | -28.749         |
| maed3-gcp49 (B5)  | base1-d3 | maed3-gcp49 | Fixed         | 0.013            | 0.024            | 18°46'55"    | 3456.345                | -30.800         |
| maed3-gcp50 (B6)  | base1-d3 | maed3-gcp50 | Fixed         | 0.015            | 0.027            | 12°58'52"    | 4220.413                | -34.032         |
| maed3-gcp51 (B7)  | base1-d3 | maed3-gcp51 | Fixed         | 0.013            | 0.023            | 7°04'37"     | 4739.215                | -34.350         |
| maed3-gcp52 (B8)  | base1-d3 | maed3-gcp52 | Fixed         | 0.010            | 0.019            | 353°27'25"   | 4717.485                | -35.584         |
| maed3-gcp53 (B9)  | base1-d3 | maed3-gcp53 | Fixed         | 0.011            | 0.021            | 341°40'02"   | 4779.827                | -44.697         |
| maed3-gcp54 (B10) | base1-d3 | maed3-gcp54 | Fixed         | 0.007            | 0.013            | 335°30'24"   | 4906.525                | -35.536         |
| maed3-gcp55 (B11) | base1-d3 | maed3-gcp55 | Fixed         | 0.014            | 0.027            | 331°50'02"   | 5017.179                | -46.843         |
| maed3-gcp56 (B12) | base1-d3 | maed3-gcp56 | Fixed         | 0.013            | 0.024            | 331°50'01"   | 5017.181                | -46.850         |
| maed3-gcp57 (B13) | base1-d3 | maed3-gcp57 | Fixed         | 0.013            | 0.023            | 324°26'18"   | 5340.966                | -40.274         |

#### Acceptance Summary

| Processed | Passed | Flag |  | Fail |  |
|-----------|--------|------|-------------------------------------------------------------------------------------|------|-------------------------------------------------------------------------------------|
| 13        | 13     | 0    |                                                                                     | 0    |                                                                                     |

### base1-d3 (08:56:24 AM-09:25:09 AM) (S1)

|                        |                                         |
|------------------------|-----------------------------------------|
| Baseline observation:  | maed3-gcp45 (B1)                        |
| Processed:             | 2016-08-10 04:30:44 PM                  |
| Solution type:         | Fixed                                   |
| Frequency used:        | Dual Frequency (L1, L2)                 |
| Horizontal precision:  | 0.005 m                                 |
| Vertical precision:    | 0.010 m                                 |
| RMS:                   | 0.004 m                                 |
| Maximum PDOP:          | 1.741                                   |
| Ephemeris used:        | Broadcast                               |
| Antenna model:         | NGS Absolute                            |
| Processing start time: | 2016-08-06 09:03:28 AM (Local: UTC+2hr) |
| Processing stop time:  | 2016-08-06 09:05:47 AM (Local: UTC+2hr) |
| Processing duration:   | 00:02:19                                |
| Processing interval:   | 1 second                                |

### Vector Components (Mark to Mark)

| From:     | base1-d3      |           |                  |           |                  |
|-----------|---------------|-----------|------------------|-----------|------------------|
|           | Grid          |           | Local            |           | Global           |
| Easting   | 75457.281 m   | Latitude  | S26°15'00.22259" | Latitude  | S26°15'00.22259" |
| Northing  | 2904758.879 m | Longitude | E32°14'40.99766" | Longitude | E32°14'40.99766" |
| Elevation | 116.828 m     | Height    | 116.828 m        | Height    | 116.828 m        |

| To:       | maed3-gcp45   |           |                  |           |                  |
|-----------|---------------|-----------|------------------|-----------|------------------|
|           | Grid          |           | Local            |           | Global           |
| Easting   | 75458.788 m   | Latitude  | S26°15'00.15208" | Latitude  | S26°15'00.15208" |
| Northing  | 2904756.717 m | Longitude | E32°14'40.94380" | Longitude | E32°14'40.94380" |
| Elevation | 116.802 m     | Height    | 116.802 m        | Height    | 116.802 m        |

|            |          |                 |            |    |          |
|------------|----------|-----------------|------------|----|----------|
| Vector     |          |                 |            |    |          |
| ΔEasting   | 1.507 m  | NS Fwd Azimuth  | 145°26'31" | ΔX | 1.589 m  |
| ΔNorthing  | -2.161 m | Ellipsoid Dist. | 2.635 m    | ΔY | -0.764 m |
| ΔElevation | -0.026 m | ΔHeight         | -0.026 m   | ΔZ | 1.958 m  |

## Standard Errors

| Vector errors:                   |         |                                  |          |                   |         |
|----------------------------------|---------|----------------------------------|----------|-------------------|---------|
| $\sigma \Delta \text{Easting}$   | 0.002 m | $\sigma \text{ NS fwd Azimuth}$  | 0°02'26" | $\sigma \Delta X$ | 0.004 m |
| $\sigma \Delta \text{Northing}$  | 0.002 m | $\sigma \text{ Ellipsoid Dist.}$ | 0.002 m  | $\sigma \Delta Y$ | 0.003 m |
| $\sigma \Delta \text{Elevation}$ | 0.005 m | $\sigma \Delta \text{Height}$    | 0.005 m  | $\sigma \Delta Z$ | 0.002 m |

## Aposteriori Covariance Matrix (Meter<sup>2</sup>)

|   | X             | Y             | Z            |
|---|---------------|---------------|--------------|
| X | 0.0000189921  |               |              |
| Y | 0.0000107863  | 0.0000105570  |              |
| Z | -0.0000058472 | -0.0000039754 | 0.0000049914 |

## Occupations

|                            | From                                                                                                   | To                                                                                                     |
|----------------------------|--------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| Point ID:                  | base1-d3                                                                                               | maed3-gcp45                                                                                            |
| Data file:                 | C:\Users\Agri-sense\Documents\1_AgrisenseData\MAE61\Trimble\TrimbleData\mae61_d3\mae61_d3\11272190.T02 | C:\Users\Agri-sense\Documents\1_AgrisenseData\MAE61\Trimble\TrimbleData\mae61_d3\mae61_d3\58582190.T02 |
| Receiver type:             | R4-3                                                                                                   | R4-3                                                                                                   |
| Receiver serial number:    | 5544441127                                                                                             | 5537435858                                                                                             |
| Antenna type:              | R4-3 Internal                                                                                          | R4-3 Internal                                                                                          |
| Antenna serial number:     | 54444127                                                                                               | 37435858                                                                                               |
| Antenna height (measured): | 1.885 m                                                                                                | 2.000 m                                                                                                |
| Antenna method:            | Bottom of antenna mount                                                                                | Bottom of antenna mount                                                                                |

## Tracking Summary

| SV   | 2016-08-06 09:03:28 AM | Duration: 00:02:19 | Major interval: 00:01:00 | 2016-08-06 09:05:47 AM |
|------|------------------------|--------------------|--------------------------|------------------------|
| G 2  | L1<br>L2               |                    |                          |                        |
| G 5  | L1<br>L2               |                    |                          |                        |
| G 13 | L1<br>L2               |                    |                          |                        |
| G 15 | L1<br>L2               |                    |                          |                        |
| G 20 | L1<br>L2               |                    |                          |                        |
| G 21 | L1<br>L2               |                    |                          |                        |
| G 24 | L1<br>L2               |                    |                          |                        |
| G 29 | L1<br>L2               |                    |                          |                        |
| R 3  | L1<br>L2               |                    |                          |                        |
| R 4  | L1<br>L2               |                    |                          |                        |
| R 13 | L1<br>L2               |                    |                          |                        |
| R 14 | L1<br>L2               |                    |                          |                        |
| R 17 | L1<br>L2               |                    |                          |                        |
| R 18 | L1<br>L2               |                    |                          |                        |
| R 19 | L1<br>L2               |                    |                          |                        |

| Project file data |                                                                                               | Coordinate System |          |
|-------------------|-----------------------------------------------------------------------------------------------|-------------------|----------|
| Name:             | C:\Users\Agri-sense\Documents\1_AgrisenseData\MAE61\Trimble\TrimbleData\mae61_d4\mae61_d4.vce | Name:             | Default  |
| Size:             | 84 KB                                                                                         | Datum:            | WGS 1984 |
| Modified:         | 2016-08-10 05:00:42 PM (UTC:2)                                                                | Zone:             | Default  |
| Time zone:        | South Africa Standard Time                                                                    | Geoid:            |          |
| Reference number: |                                                                                               | Vertical datum:   |          |
| Description:      |                                                                                               |                   |          |
| Comment 1:        |                                                                                               |                   |          |
| Comment 2:        |                                                                                               |                   |          |
| Comment 3:        |                                                                                               |                   |          |

#### Additional Coordinate System Details

| Local Site Settings |         |                        |       |
|---------------------|---------|------------------------|-------|
| Project latitude:   | ?       | Ground scale factor:   | 1     |
| Project longitude:  | ?       | False northing offset: | 0.000 |
| Project height:     | 100.000 | False easting offset:  | 0.000 |

### Baseline Processing Report

#### Processing Summary

| Observation       | From     | To          | Solution Type | H. Prec. (Meter) | V. Prec. (Meter) | Geodetic Az. | Ellipsoid Dist. (Meter) | ΔHeight (Meter) |
|-------------------|----------|-------------|---------------|------------------|------------------|--------------|-------------------------|-----------------|
| maed4-gcp70 (B1)  | base1-d4 | maed4-gcp70 | Fixed         | 0.009            | 0.021            | 325°47'27"   | 1397.074                | -20.633         |
| maed4-gcp71 (B2)  | base1-d4 | maed4-gcp71 | Fixed         | 0.010            | 0.025            | 299°48'20"   | 1718.064                | -15.725         |
| maed4-gcp72 (B3)  | base1-d4 | maed4-gcp72 | Fixed         | 0.008            | 0.021            | 299°32'35"   | 2626.116                | -42.565         |
| maed4-gcp73 (B4)  | base1-d4 | maed4-gcp73 | Fixed         | 0.009            | 0.023            | 295°40'23"   | 3329.764                | -42.663         |
| maed4-gcp74 (B5)  | base1-d4 | maed4-gcp74 | Fixed         | 0.009            | 0.023            | 287°46'10"   | 3843.320                | -39.565         |
| maed4-gcp75 (B6)  | base1-d4 | maed4-gcp75 | Fixed         | 0.010            | 0.026            | 280°48'41"   | 4545.992                | -42.102         |
| maed4-gcp76 (B7)  | base1-d4 | maed4-gcp76 | Fixed         | 0.009            | 0.023            | 275°26'32"   | 5250.305                | -39.324         |
| maed4-gcp77 (B8)  | base1-d4 | maed4-gcp77 | Fixed         | 0.010            | 0.024            | 272°03'22"   | 5943.995                | -45.234         |
| maed4-gcp78 (B9)  | base1-d4 | maed4-gcp78 | Fixed         | 0.017            | 0.039            | 270°37'53"   | 6670.529                | -53.144         |
| maed4-gcp79 (B10) | base1-d4 | maed4-gcp79 | Fixed         | 0.037            | 0.086            | 270°32'29"   | 6669.939                | -53.199         |
| maed4-gcp80 (B11) | base1-d4 | maed4-gcp80 | Fixed         | 0.011            | 0.024            | 269°19'45"   | 6609.110                | -53.665         |
| maed4-gcp81 (B12) | base1-d4 | maed4-gcp81 | Fixed         | 0.010            | 0.020            | 264°58'21"   | 5865.401                | -44.786         |
| maed4-gcp82 (B13) | base1-d4 | maed4-gcp82 | Fixed         | 0.013            | 0.025            | 256°54'07"   | 5999.036                | -47.720         |
| maed4-gcp83 (B14) | base1-d4 | maed4-gcp83 | Fixed         | 0.013            | 0.025            | 256°54'07"   | 5999.040                | -47.716         |
| maed4-gcp84 (B15) | base1-d4 | maed4-gcp84 | Fixed         | 0.012            | 0.021            | 251°19'59"   | 2179.843                | -23.940         |
| maed4-gcp85 (B16) | base1-d4 | maed4-gcp85 | Fixed         | 0.011            | 0.020            | 252°09'57"   | 2659.960                | 33.947          |



|                   |          |             |       |       |       |            |          |         |
|-------------------|----------|-------------|-------|-------|-------|------------|----------|---------|
| maed4-gcp86 (B17) | base1-d4 | maed4-gcp86 | Fixed | 0.013 | 0.021 | 253°26'01" | 3415.110 | -39.131 |
| maed4-gcp87 (B18) | base1-d4 | maed4-gcp87 | Fixed | 0.011 | 0.017 | 273°26'04" | 2692.765 | -46.182 |
| maed4-gcp88 (B19) | base1-d4 | maed4-gcp88 | Fixed | 0.014 | 0.024 | 241°50'00" | 3677.059 | -46.491 |
| maed4-gcp89 (B20) | base1-d4 | maed4-gcp89 | Fixed | 0.017 | 0.031 | 230°21'11" | 3766.122 | -52.845 |
| maed4-gcp90 (B21) | base1-d4 | maed4-gcp90 | Fixed | 0.016 | 0.029 | 230°21'08" | 3766.084 | -52.840 |
| maed4-gcp91 (B22) | base1-d4 | maed4-gcp91 | Fixed | 0.011 | 0.021 | 223°34'51" | 3090.619 | -40.508 |
| maed4-gcp92 (B23) | base1-d4 | maed4-gcp92 | Fixed | 0.015 | 0.028 | 246°55'48" | 4713.683 | -61.223 |
| maed4-gcp93 (B24) | base1-d4 | maed4-gcp93 | Fixed | 0.013 | 0.025 | 265°44'48" | 4066.170 | -49.275 |
| maed4-gcp94 (B25) | base1-d4 | maed4-gcp94 | Fixed | 0.011 | 0.019 | 262°03'00" | 4803.980 | -47.320 |

### Acceptance Summary

| Processed | Passed | Flag | Fail |
|-----------|--------|------|------|
| 25        | 25     | 0    | 0    |

### base1-d4 (08:47:32 AM-03:59:12 PM) (S1)

|                        |                                         |
|------------------------|-----------------------------------------|
| Baseline observation:  | maed4-gcp70 (B1)                        |
| Processed:             | 2016-08-10 04:49:25 PM                  |
| Solution type:         | Fixed                                   |
| Frequency used:        | Dual Frequency (L1, L2)                 |
| Horizontal precision:  | 0.009 m                                 |
| Vertical precision:    | 0.021 m                                 |
| RMS:                   | 0.007 m                                 |
| Maximum PDOP:          | 1.456                                   |
| Ephemeris used:        | Broadcast                               |
| Antenna model:         | NGS Absolute                            |
| Processing start time: | 2016-08-07 09:02:21 AM (Local: UTC+2hr) |
| Processing stop time:  | 2016-08-07 09:03:24 AM (Local: UTC+2hr) |
| Processing duration:   | 00:01:03                                |
| Processing interval:   | 1 second                                |

### Vector Components (Mark to Mark)

|                  |               |                  |                  |                  |                  |
|------------------|---------------|------------------|------------------|------------------|------------------|
| From:            | base1-d4      |                  |                  |                  |                  |
| <b>Grid</b>      |               | <b>Local</b>     |                  | <b>Global</b>    |                  |
| <b>Easting</b>   | 75835.723 m   | <b>Latitude</b>  | S26°14'31.40967" | <b>Latitude</b>  | S26°14'31.40967" |
| <b>Northing</b>  | 2903874.281 m | <b>Longitude</b> | E32°14'27.54868" | <b>Longitude</b> | E32°14'27.54868" |
| <b>Elevation</b> | 124.238 m     | <b>Height</b>    | 124.238 m        | <b>Height</b>    | 124.238 m        |

|                  |               |                  |                  |                  |                  |
|------------------|---------------|------------------|------------------|------------------|------------------|
| To:              | maed4-gcp70   |                  |                  |                  |                  |
| <b>Grid</b>      |               | <b>Local</b>     |                  | <b>Global</b>    |                  |
| <b>Easting</b>   | 75043.456 m   | <b>Latitude</b>  | S26°15'08.95069" | <b>Latitude</b>  | S26°15'08.95069" |
| <b>Northing</b>  | 2905025.108 m | <b>Longitude</b> | E32°14'55.85263" | <b>Longitude</b> | E32°14'55.85263" |
| <b>Elevation</b> | 103.605 m     | <b>Height</b>    | 103.605 m        | <b>Height</b>    | 103.605 m        |

|                   |            |                        |            |           |             |
|-------------------|------------|------------------------|------------|-----------|-------------|
| <b>Vector</b>     |            |                        |            |           |             |
| <b>ΔEasting</b>   | -792.267 m | <b>NS Fwd Azimuth</b>  | 325°47'27" | <b>ΔX</b> | -866.903 m  |
| <b>ΔNorthing</b>  | 1150.827 m | <b>Ellipsoid Dist.</b> | 1397.074 m | <b>ΔY</b> | 381.872 m   |
| <b>ΔElevation</b> | -20.633 m  | <b>ΔHeight</b>         | -20.633 m  | <b>ΔZ</b> | -1027.114 m |

### Standard Errors

|                       |         |                          |          |             |         |
|-----------------------|---------|--------------------------|----------|-------------|---------|
| <b>Vector errors:</b> |         |                          |          |             |         |
| <b>σ ΔEasting</b>     | 0.004 m | <b>σ NS fwd Azimuth</b>  | 0°00'01" | <b>σ ΔX</b> | 0.009 m |
| <b>σ ΔNorthing</b>    | 0.004 m | <b>σ Ellipsoid Dist.</b> | 0.004 m  | <b>σ ΔY</b> | 0.007 m |
| <b>σ ΔElevation</b>   | 0.011 m | <b>σ ΔHeight</b>         | 0.011 m  | <b>σ ΔZ</b> | 0.005 m |

### Aposteriori Covariance Matrix (Meter<sup>2</sup>)

|          |               |               |              |
|----------|---------------|---------------|--------------|
|          | <b>X</b>      | <b>Y</b>      | <b>Z</b>     |
| <b>X</b> | 0.0000758903  |               |              |
| <b>Y</b> | 0.0000439431  | 0.0000440375  |              |
| <b>Z</b> | -0.0000262602 | -0.0000186533 | 0.0000222091 |

## Occupations

|                                   | From                                                                                                               | To                                                                                                                 |
|-----------------------------------|--------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|
| <b>Point ID:</b>                  | base1-d4                                                                                                           | maed4-gcp70                                                                                                        |
| <b>Data file:</b>                 | C:\Users\Agri-sense\Documents<br>\1_AgrisenseData\MAE61\Trimble<br>\TrimbleData<br>\mae61_d4\mae61_d4\11272200.T02 | C:\Users\Agri-sense\Documents<br>\1_AgrisenseData\MAE61\Trimble<br>\TrimbleData<br>\mae61_d4\mae61_d4\58582200.T02 |
| <b>Receiver type:</b>             | R4-3                                                                                                               | R4-3                                                                                                               |
| <b>Receiver serial number:</b>    | 5544441127                                                                                                         | 5537435858                                                                                                         |
| <b>Antenna type:</b>              | R4-3 Internal                                                                                                      | R4-3 Internal                                                                                                      |
| <b>Antenna serial number:</b>     | 54444127                                                                                                           | 37435858                                                                                                           |
| <b>Antenna height (measured):</b> | 1.880 m                                                                                                            | 2.000 m                                                                                                            |
| <b>Antenna method:</b>            | Bottom of antenna mount                                                                                            | Bottom of antenna mount                                                                                            |

| Project file data |                                                                                               | Coordinate System |          |
|-------------------|-----------------------------------------------------------------------------------------------|-------------------|----------|
| Name:             | C:\Users\Agri-sense\Documents\1_AgrisenseData\MAE61\Trimble\TrimbleData\mae61_d5\mae61_d5.vce | Name:             | Default  |
| Size:             | 79 KB                                                                                         | Datum:            | WGS 1984 |
| Modified:         | 2016-08-10 05:00:08 PM (UTC:2)                                                                | Zone:             | Default  |
| Time zone:        | South Africa Standard Time                                                                    | Geoid:            |          |
| Reference number: |                                                                                               | Vertical datum:   |          |
| Description:      |                                                                                               |                   |          |
| Comment 1:        |                                                                                               |                   |          |
| Comment 2:        |                                                                                               |                   |          |
| Comment 3:        |                                                                                               |                   |          |

#### Additional Coordinate System Details

| Local Site Settings |         |                        |       |
|---------------------|---------|------------------------|-------|
| Project latitude:   | ?       | Ground scale factor:   | 1     |
| Project longitude:  | ?       | False northing offset: | 0.000 |
| Project height:     | 100.000 | False easting offset:  | 0.000 |

### Baseline Processing Report

#### Processing Summary

| Observation       | From     | To          | Solution Type | H. Prec. (Meter) | V. Prec. (Meter) | Geodetic Az. | Ellipsoid Dist. (Meter) | ΔHeight (Meter) |
|-------------------|----------|-------------|---------------|------------------|------------------|--------------|-------------------------|-----------------|
| maed1-gcp19 (B1)  | base1-d5 | maed1-gcp19 | Fixed         | 0.011            | 0.022            | 297°05'31"   | 3340.296                | -31.724         |
| maed5-gcp3 (B3)   | base1-d5 | maed5-gcp3  | Fixed         | 0.007            | 0.015            | 297°07'03"   | 3357.595                | -31.278         |
| maed5-gcp4 (B4)   | base1-d5 | maed5-gcp4  | Fixed         | 0.011            | 0.029            | 312°43'05"   | 3758.057                | -33.644         |
| maed5-gcp5 (B5)   | base1-d5 | maed5-gcp5  | Fixed         | 0.011            | 0.029            | 320°08'34"   | 4232.605                | -37.599         |
| maed5-gcp6 (B6)   | base1-d5 | maed5-gcp6  | Fixed         | 0.012            | 0.030            | 323°49'39"   | 4497.999                | -40.621         |
| maed5-gcp7 (B7)   | base1-d5 | maed5-gcp7  | Fixed         | 0.012            | 0.030            | 326°04'54"   | 4973.898                | -41.749         |
| maed5-gcp8 (B8)   | base1-d5 | maed5-gcp8  | Fixed         | 0.010            | 0.019            | 320°10'05"   | 3419.608                | -41.651         |
| maed5-gcp9 (B9)   | base1-d5 | maed5-gcp9  | Fixed         | 0.010            | 0.019            | 325°57'51"   | 3092.170                | -42.480         |
| maed5-gcp10 (B10) | base1-d5 | maed5-gcp10 | Fixed         | 0.011            | 0.020            | 337°23'13"   | 3178.551                | -37.518         |
| maed5-gcp11 (B11) | base1-d5 | maed5-gcp11 | Fixed         | 0.011            | 0.020            | 339°20'43"   | 3540.802                | -41.157         |
| maed5-gcp12 (B12) | base1-d5 | maed5-gcp12 | Fixed         | 0.009            | 0.016            | 329°02'24"   | 2465.360                | -38.214         |
| maed5-gcp13 (B13) | base1-d5 | maed5-gcp13 | Fixed         | 0.008            | 0.015            | 321°35'17"   | 2772.599                | -40.960         |
| maed5-gcp14 (B14) | base1-d5 | maed5-gcp14 | Fixed         | 0.011            | 0.021            | 277°06'58"   | 4174.960                | -29.534         |
| maed5-gcp15 (B15) | base1-d5 | maed5-gcp15 | Fixed         | 0.012            | 0.021            | 284°44'16"   | 4281.307                | -25.223         |
| maed5-gcp16 (B16) | base1-d5 | maed5-gcp16 | Fixed         | 0.012            | 0.021            | 291°22'10"   | 4063.885                | -24.954         |
| maed5-gcp17 (B17) | base1-d5 | maed5-gcp17 | Fixed         | 0.012            | 0.021            | 291°22'10"   | 4063.880                | -24.954         |

|                   |          |             |       |       |       |            |          |         |
|-------------------|----------|-------------|-------|-------|-------|------------|----------|---------|
| maed5-gcp18 (B18) | base1-d5 | maed5-gcp18 | Fixed | 0.013 | 0.021 | 297°39'38" | 4477.957 | -23.720 |
| maed5-gcp19 (B19) | base1-d5 | maed5-gcp19 | Fixed | 0.010 | 0.015 | 271°32'21" | 5857.748 | -40.505 |
| maed5-gcp20 (B20) | base1-d5 | maed5-gcp20 | Fixed | 0.012 | 0.019 | 271°07'13" | 6374.348 | -47.413 |
| maed5-gcp21 (B21) | base1-d5 | maed5-gcp21 | Fixed | 0.012 | 0.022 | 281°59'12" | 6357.593 | -44.177 |
| maed5-gcp22 (B22) | base1-d5 | maed5-gcp22 | Fixed | 0.011 | 0.023 | 283°54'39" | 5744.514 | -36.941 |
| maed5-gcp23 (B23) | base1-d5 | maed5-gcp23 | Fixed | 0.011 | 0.021 | 286°53'51" | 5382.113 | -33.064 |
| maed5-gcp24 (B24) | base1-d5 | maed5-gcp24 | Fixed | 0.011 | 0.020 | 291°22'53" | 4920.835 | -29.374 |
| maed5-gcp25 (B25) | base1-d5 | maed5-gcp25 | Fixed | 0.010 | 0.018 | 301°59'45" | 4215.566 | -25.272 |
| maed5-gcp26 (B26) | base1-d5 | maed5-gcp26 | Fixed | 0.012 | 0.022 | 298°22'08" | 5040.187 | -26.958 |
| maed5-gcp27 (B27) | base1-d5 | maed5-gcp27 | Fixed | 0.008 | 0.016 | 304°20'06" | 5264.327 | -27.593 |

### Acceptance Summary

| Processed | Passed | Flag | Fail |
|-----------|--------|------|------|
| 26        | 26     | 0    | 0    |

### base1-d5 (08:31:04 AM-08:52:59 AM) (S1)

|                        |                                         |
|------------------------|-----------------------------------------|
| Baseline observation:  | maed1-gcp19 (B1)                        |
| Processed:             | 2016-08-10 04:38:34 PM                  |
| Solution type:         | Fixed                                   |
| Frequency used:        | Dual Frequency (L1, L2)                 |
| Horizontal precision:  | 0.011 m                                 |
| Vertical precision:    | 0.022 m                                 |
| RMS:                   | 0.006 m                                 |
| Maximum PDOP:          | 1.418                                   |
| Ephemeris used:        | Broadcast                               |
| Antenna model:         | NGS Absolute                            |
| Processing start time: | 2016-08-08 08:46:15 AM (Local: UTC+2hr) |
| Processing stop time:  | 2016-08-08 08:46:38 AM (Local: UTC+2hr) |
| Processing duration:   | 00:00:23                                |
| Processing interval:   | 1 second                                |

### Vector Components (Mark to Mark)

|           |               |           |                  |           |                  |
|-----------|---------------|-----------|------------------|-----------|------------------|
| From:     | base1-d5      |           |                  |           |                  |
| Grid      |               | Local     |                  | Global    |                  |
| Easting   | 75460.785 m   | Latitude  | S26°15'00.30175" | Latitude  | S26°15'00.30175" |
| Northing  | 2904761.336 m | Longitude | E32°14'40.87086" | Longitude | E32°14'40.87086" |
| Elevation | 116.976 m     | Height    | 116.976 m        | Height    | 116.976 m        |

|           |               |           |                  |           |                  |
|-----------|---------------|-----------|------------------|-----------|------------------|
| To:       | maed1-gcp19   |           |                  |           |                  |
| Grid      |               | Local     |                  | Global    |                  |
| Easting   | 72477.977 m   | Latitude  | S26°15'49.72089" | Latitude  | S26°15'49.72089" |
| Northing  | 2906265.310 m | Longitude | E32°16'28.04176" | Longitude | E32°16'28.04176" |
| Elevation | 85.252 m      | Height    | 85.252 m         | Height    | 85.252 m         |

|                   |             |                        |            |           |             |
|-------------------|-------------|------------------------|------------|-----------|-------------|
| <b>Vector</b>     |             |                        |            |           |             |
| <b>ΔEasting</b>   | -2982.808 m | <b>NS Fwd Azimuth</b>  | 297°05'31" | <b>ΔX</b> | -2180.443 m |
| <b>ΔNorthing</b>  | 1503.974 m  | <b>Ellipsoid Dist.</b> | 3340.296 m | <b>ΔY</b> | 2140.610 m  |
| <b>ΔElevation</b> | -31.724 m   | <b>ΔHeight</b>         | -31.724 m  | <b>ΔZ</b> | -1349.960 m |

### Standard Errors

|                       |         |                          |          |             |         |
|-----------------------|---------|--------------------------|----------|-------------|---------|
| <b>Vector errors:</b> |         |                          |          |             |         |
| <b>σ ΔEasting</b>     | 0.004 m | <b>σ NS fwd Azimuth</b>  | 0°00'00" | <b>σ ΔX</b> | 0.009 m |
| <b>σ ΔNorthing</b>    | 0.004 m | <b>σ Ellipsoid Dist.</b> | 0.004 m  | <b>σ ΔY</b> | 0.007 m |
| <b>σ ΔElevation</b>   | 0.011 m | <b>σ ΔHeight</b>         | 0.011 m  | <b>σ ΔZ</b> | 0.006 m |

### Aposteriori Covariance Matrix (Meter<sup>2</sup>)

|          |               |               |              |
|----------|---------------|---------------|--------------|
|          | <b>X</b>      | <b>Y</b>      | <b>Z</b>     |
| <b>X</b> | 0.0000840430  |               |              |
| <b>Y</b> | 0.0000477675  | 0.0000517094  |              |
| <b>Z</b> | -0.0000303744 | -0.0000221450 | 0.0000309203 |

## Occupations

|                                   | From                                                                                                               | To                                                                                                                 |
|-----------------------------------|--------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|
| <b>Point ID:</b>                  | base1-d5                                                                                                           | maed1-gcp19                                                                                                        |
| <b>Data file:</b>                 | C:\Users\Agri-sense\Documents<br>\1_AgrisenseData\MAE61\Trimble<br>\TrimbleData<br>\mae61_d5\mae61_d5\11272211.T02 | C:\Users\Agri-sense\Documents<br>\1_AgrisenseData\MAE61\Trimble<br>\TrimbleData<br>\mae61_d5\mae61_d5\58582210.T02 |
| <b>Receiver type:</b>             | R4-3                                                                                                               | R4-3                                                                                                               |
| <b>Receiver serial number:</b>    | 5544441127                                                                                                         | 5537435858                                                                                                         |
| <b>Antenna type:</b>              | R4-3 Internal                                                                                                      | R4-3 Internal                                                                                                      |
| <b>Antenna serial number:</b>     | 54444127                                                                                                           | 37435858                                                                                                           |
| <b>Antenna height (measured):</b> | 1.739 m                                                                                                            | 2.000 m                                                                                                            |
| <b>Antenna method:</b>            | Bottom of antenna mount                                                                                            | Bottom of antenna mount                                                                                            |



| Project file data |                                                                                               | Coordinate System |          |
|-------------------|-----------------------------------------------------------------------------------------------|-------------------|----------|
| Name:             | C:\Users\Agri-sense\Documents\1_AgrisenseData\MAE61\Trimble\TrimbleData\mae61_d6\mae61_d6.vce | Name:             | Default  |
| Size:             | 88 KB                                                                                         | Datum:            | WGS 1984 |
| Modified:         | 2016-08-10 04:59:15 PM (UTC:2)                                                                | Zone:             | Default  |
| Time zone:        | South Africa Standard Time                                                                    | Geoid:            |          |
| Reference number: |                                                                                               | Vertical datum:   |          |
| Description:      |                                                                                               |                   |          |
| Comment 1:        |                                                                                               |                   |          |
| Comment 2:        |                                                                                               |                   |          |
| Comment 3:        |                                                                                               |                   |          |

#### Additional Coordinate System Details

| Local Site Settings |         |                        |       |
|---------------------|---------|------------------------|-------|
| Project latitude:   | ?       | Ground scale factor:   | 1     |
| Project longitude:  | ?       | False northing offset: | 0.000 |
| Project height:     | 100.000 | False easting offset:  | 0.000 |

### Baseline Processing Report

#### Processing Summary

| Observation           | From     | To              | Solution Type | H. Prec. (Meter) | V. Prec. (Meter) | Geodetic Az. | Ellipsoid Dist. (Meter) | ΔHeight (Meter) |
|-----------------------|----------|-----------------|---------------|------------------|------------------|--------------|-------------------------|-----------------|
| maed6-gcp1 (B1)       | base1-d6 | maed6-gcp1      | Fixed         | 0.010            | 0.026            | 303°47'00"   | 5597.705                | -23.201         |
| maed6-gcp2 (B2)       | base1-d6 | maed6-gcp2      | Fixed         | 0.011            | 0.026            | 299°45'18"   | 6170.943                | -25.513         |
| maed6-gcp3 (B3)       | base1-d6 | maed6-gcp3      | Fixed         | 0.012            | 0.027            | 295°21'32"   | 6568.175                | -28.029         |
| maed6-gcp4 (B4)       | base1-d6 | maed6-gcp4      | Fixed         | 0.013            | 0.027            | 293°24'22"   | 7502.454                | -30.576         |
| maed6-gcp5 (B5)       | base1-d6 | maed6-gcp5      | Fixed         | 0.014            | 0.024            | 284°29'15"   | 6179.391                | -26.992         |
| maed6-gcp6 (B6)       | base1-d6 | maed6-gcp6      | Fixed         | 0.011            | 0.020            | 291°38'26"   | 4942.591                | -8.707          |
| maed6-gcp7 (B7)       | base1-d6 | maed6-gcp7      | Fixed         | 0.011            | 0.021            | 281°04'50"   | 5315.665                | -18.505         |
| maed6-gcp8 (B8)       | base1-d6 | maed6-gcp8      | Fixed         | 0.014            | 0.023            | 260°02'30"   | 9771.407                | -11.648         |
| maed6-gcp9 (B9)       | base1-d6 | maed6-gcp9      | Fixed         | 0.014            | 0.024            | 260°07'50"   | 9271.808                | -9.166          |
| maed6-bench1-43 (B10) | base1-d6 | maed6-bench1-43 | Fixed         | 0.010            | 0.016            | 260°20'10"   | 8436.656                | -8.812          |
| maed6-gcp10 (B11)     | base1-d6 | maed6-gcp10     | Fixed         | 0.012            | 0.022            | 260°18'40"   | 8413.112                | -9.327          |
| maed6-bench2 (B12)    | base1-d6 | maed6-bench2    | Fixed         | 0.011            | 0.018            | 260°22'43"   | 9073.437                | -7.632          |
| maed6-gcp11 (B13)     | base1-d6 | maed6-gcp11     | Fixed         | 0.013            | 0.021            | 259°37'02"   | 10980.248               | -22.990         |
| maed6-gcp12 (B14)     | base1-d6 | maed6-gcp12     | Fixed         | 0.012            | 0.020            | 278°01'32"   | 7575.106                | -26.287         |

#### Acceptance Summary

| Processed | Passed | Flag |  | Fail |  |
|-----------|--------|------|-------------------------------------------------------------------------------------|------|-------------------------------------------------------------------------------------|
| 14        | 14     | 0    |                                                                                     | 0    |                                                                                     |

### base1-d6 (09:13:33 AM-04:41:56 PM) (S1)

|                        |                                         |
|------------------------|-----------------------------------------|
| Baseline observation:  | maed6-gcp1 (B1)                         |
| Processed:             | 2016-08-10 04:49:32 PM                  |
| Solution type:         | Fixed                                   |
| Frequency used:        | Dual Frequency (L1, L2)                 |
| Horizontal precision:  | 0.010 m                                 |
| Vertical precision:    | 0.026 m                                 |
| RMS:                   | 0.013 m                                 |
| Maximum PDOP:          | 1.654                                   |
| Ephemeris used:        | Broadcast                               |
| Antenna model:         | NGS Absolute                            |
| Processing start time: | 2016-08-09 09:35:06 AM (Local: UTC+2hr) |
| Processing stop time:  | 2016-08-09 09:37:37 AM (Local: UTC+2hr) |
| Processing duration:   | 00:02:31                                |
| Processing interval:   | 1 second                                |

### Vector Components (Mark to Mark)

| From:     | base1-d6      |           |                  |           |                  |
|-----------|---------------|-----------|------------------|-----------|------------------|
|           | Grid          |           | Local            |           | Global           |
| Easting   | 79992.778 m   | Latitude  | S26°17'35.12959" | Latitude  | S26°17'35.12959" |
| Northing  | 2909553.942 m | Longitude | E32°11'56.51036" | Longitude | E32°11'56.51036" |
| Elevation | 95.373 m      | Height    | 95.373 m         | Height    | 95.373 m         |

| To:       | maed6-gcp1    |           |                  |           |                  |
|-----------|---------------|-----------|------------------|-----------|------------------|
|           | Grid          |           | Local            |           | Global           |
| Easting   | 75320.725 m   | Latitude  | S26°19'16.24133" | Latitude  | S26°19'16.24133" |
| Northing  | 2912637.915 m | Longitude | E32°14'44.26257" | Longitude | E32°14'44.26257" |
| Elevation | 72.172 m      | Height    | 72.172 m         | Height    | 72.172 m         |

|            |             |                 |            |    |             |
|------------|-------------|-----------------|------------|----|-------------|
| Vector     |             |                 |            |    |             |
| ΔEasting   | -4672.053 m | NS Fwd Azimuth  | 303°47'00" | ΔX | -3665.380 m |
| ΔNorthing  | 3083.973 m  | Ellipsoid Dist. | 5597.705 m | ΔY | 3190.042 m  |
| ΔElevation | -23.201 m   | ΔHeight         | -23.201 m  | ΔZ | -2779.260 m |

## Standard Errors

| Vector errors:                   |         |                                  |          |                   |         |
|----------------------------------|---------|----------------------------------|----------|-------------------|---------|
| $\sigma \Delta \text{Easting}$   | 0.004 m | $\sigma \text{ NS fwd Azimuth}$  | 0°00'00" | $\sigma \Delta X$ | 0.011 m |
| $\sigma \Delta \text{Northing}$  | 0.004 m | $\sigma \text{ Ellipsoid Dist.}$ | 0.004 m  | $\sigma \Delta Y$ | 0.008 m |
| $\sigma \Delta \text{Elevation}$ | 0.013 m | $\sigma \Delta \text{Height}$    | 0.013 m  | $\sigma \Delta Z$ | 0.006 m |

## Aposteriori Covariance Matrix (Meter<sup>2</sup>)

|   | X             | Y             | Z            |
|---|---------------|---------------|--------------|
| X | 0.0001124539  |               |              |
| Y | 0.0000641797  | 0.0000598490  |              |
| Z | -0.0000467136 | -0.0000313197 | 0.0000366797 |

## Occupations

|                            | From                                                                                                   | To                                                                                                     |
|----------------------------|--------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| Point ID:                  | base1-d6                                                                                               | maed6-gcp1                                                                                             |
| Data file:                 | C:\Users\Agri-sense\Documents\1_AgrisenseData\MAE61\Trimble\TrimbleData\mae61_d6\mae61_d6\11272220.T02 | C:\Users\Agri-sense\Documents\1_AgrisenseData\MAE61\Trimble\TrimbleData\mae61_d6\mae61_d6\58582220.T02 |
| Receiver type:             | R4-3                                                                                                   | R4-3                                                                                                   |
| Receiver serial number:    | 5544441127                                                                                             | 5537435858                                                                                             |
| Antenna type:              | R4-3 Internal                                                                                          | R4-3 Internal                                                                                          |
| Antenna serial number:     | 54444127                                                                                               | 37435858                                                                                               |
| Antenna height (measured): | 1.873 m                                                                                                | 2.000 m                                                                                                |
| Antenna method:            | Bottom of antenna mount                                                                                | Bottom of antenna mount                                                                                |

## Tracking Summary

| SV   | 2016-08-09 09:35:06 AM | Duration: 00:02:31 | Major interval: 00:01:00 | 2016-08-09 09:37:37 AM |
|------|------------------------|--------------------|--------------------------|------------------------|
| G 2  | L1<br>L2               |                    |                          |                        |
| G 5  | L1<br>L2               |                    |                          |                        |
| G 13 | L1<br>L2               |                    |                          |                        |
| G 15 | L1<br>L2               |                    |                          |                        |
| G 18 | L1<br>L2               |                    |                          |                        |
| G 20 | L1<br>L2               |                    |                          |                        |
| G 21 | L1<br>L2               |                    |                          |                        |
| G 24 | L1<br>L2               |                    |                          |                        |
| G 29 | L1<br>L2               |                    |                          |                        |
| R 6  | L1<br>L2               |                    |                          |                        |
| R 7  | L1<br>L2               |                    |                          |                        |
| R 9  | L1<br>L2               |                    |                          |                        |
| R 16 | L1<br>L2               |                    |                          |                        |
| R 21 | L1<br>L2               |                    |                          |                        |
| R 22 | L1<br>L2               |                    |                          |                        |

## **Appendix 5**

### **Trimble R4 GNSS GPS Specifications**

# Trimble R4 GNSS system

## Key Features

Trimble R-Track satellite tracking technology

Includes Trimble Maxwell 6 chip with 220 channels

Scalable from postprocessing to VRS to multi-constellation RTK configurations

Cable-free for convenience

Accurate, reliable and rugged system

Trimble Slate controller



## Dependable When every point Counts

Designed for surveyors looking for easy-to-use GNSS technology, the Trimble® R4 GNSS System performs under even the most rigorous conditions. GNSS support upgrade options, integrated Trimble R-Track™ satellite tracking technology, and a straightforward system design result in a system that is flexible, reliable, and rugged.

## a complete GNSS system

Lightweight, convenient and cable-free, the Trimble R4 GNSS system with Trimble Access™ field software provides the ease of use of an integrated receiver and everything you need to perform a basic survey campaign.

The dual-frequency antenna enhances tracking capacity and delivers sub-millimeter phase center stability for precise results in demanding conditions. Internally powered with removable batteries, this system provides a full working day of uninterrupted field operation.

## advanced Trimble r-track technology

The Trimble R4, powered with a Trimble Maxwell™ 6 chip with 220 channels, delivers the accuracy and reliability required for precision surveying with superior tracking and RTK performance. With GPS L2C and the Japanese QZSS support included, you can track more satellites and measure more successfully in challenging environments. L2C provides more than just additional signals – the advanced signal structure provides better strength for more reliable satellite tracking.

Trimble R-Track satellite tracking technology delivers reliable, precise positioning performance. Trimble R-Track with Signal Prediction™ compensates for intermittent or marginal RTK correction signals, enabling extended precision operation after an RTK signal is interrupted.

The CMRx communications protocol provides correction compression for optimized bandwidth and full utilization all of the satellites in view, giving you reliable positioning performance.

## Choose the level of GNSS support you require today

Choose the level of GNSS support you require today with the flexible upgrade options available on the Trimble R4. Founded on proven GNSS technology, the Trimble R4 comes standard with GPS L1, L2, L2C and QZSS. Beyond this standard GNSS support, the Trimble R4 offers upgrades to GLONASS, Galileo, and BeiDou (COMPASS)—just choose what you need.

## Functions as a vrs rover, RTK rover, or Field base station

Use as a lightweight rover for static surveying or RTK. The Trimble R4 is also completely compatible with Trimble VRS™ solutions, creating a VRS rover for use inside real-time networks. With a built-in 450 MHz receive-only radio or a fully integrated GSM/GPRS radio, this system can be adapted to meet a variety of needs. As a base station, the Trimble R4 with the integrated UHF transmit option is rugged, weather-resistant and compatible with a range of radio solutions.

## a dedicated, reliable GNSS Field solution

Pair the Trimble R4 with Trimble Access and the Trimble Slate Controller<sup>1</sup> for a dedicated GNSS solution that is effective for both real time and postprocessed GNSS surveys.

Powerful, connected, and compact, the Trimble Slate Controller combines the convenience and ease-of-use of a smartphone with the durability for which Trimble is known. Its slim, ergonomic design is easy to grasp and its screen provides superior sunlight readability enabling all-day use by hard-working survey professionals.

Trimble Access field software provides specialized and customized workflows to make surveying tasks quicker and easier while enabling teams to communicate vital information between field and office in real-time.

Survey companies can also implement their unique workflows by taking advantage of the customization capabilities available in the Trimble Access Software Development Kit (SDK).

Need to get data back to the office immediately? Benefit from real-time data sharing via Trimble Access Services, now available with any valid Trimble Access maintenance agreement.

Back in the office, users can seamlessly process data with Trimble Business Center office software.

The Trimble R4 GNSS system —ready and reliable for your everyday surveying needs.

<sup>1</sup> The Trimble R4 can be used with a Trimble TSC3, Trimble CU, or Trimble Tablet Rugged PC with the purchase of an advanced data collector option.

# Trimble r4 GNSS system

Datasheet

## performance specifications

### measurements

- Advanced Trimble Maxwell 6 Custom Survey GNSS chip with 220 channels
- Trimble R-Track technology
- High precision multiple correlator for GNSS pseudorange measurements
- Unfiltered, unsmoothed pseudorange measurements data for low noise, low multipath error, low time domain correlation and high dynamic response
- Very low noise GNSS carrier phase measurements with <1 mm precision in a 1 Hz bandwidth
- Signal-to-Noise ratios reported in dB-Hz
- Proven Trimble low elevation tracking technology
- Satellite signals tracked simultaneously:
  - GPS: L1C/A, L1C, L2C, L2E
  - GLONASS<sup>1</sup>: L1C/A, L1P, L2C/A, L2P, L3
  - SBAS: L1C/A
  - Galileo<sup>1</sup>: E1, E5A, E5B
  - BeiDou<sup>1</sup> (COMPASS): B1, B2
- SBAS: QZSS, WAAS, EGNOS, GAGAN
- Positioning rates: 1 Hz, 2 Hz, 5 Hz, and 10 Hz

## positioning performance<sup>2</sup>

### code differential GNSS

#### positioning

Horizontal . . . . . 0.25 m + 1 ppm RMS  
Vertical . . . . . 0.50 m + 1 ppm RMS  
SBAS differential positioning accuracy<sup>3</sup> . . . . . typically <5 m 3DRMS

### static GNSS

#### surveying

##### high-precision static

Horizontal . . . . . 3 mm + 0.1 ppm RMS  
Vertical . . . . . 3.5 mm + 0.4 ppm RMS

##### static and Faststatic

Horizontal . . . . . 3 mm + 0.5 ppm RMS  
Vertical . . . . . 5 mm + 0.5 ppm RMS

### postprocessed Kinematic (PPK) GNSS

#### surveying

Horizontal . . . . . 8 mm + 1 ppm RMS  
Vertical . . . . . 15 mm + 1 ppm RMS

## real time Kinematic surveying<sup>4</sup>

### single baseline <30 km

Horizontal . . . . . 8 mm + 1 ppm RMS  
Vertical . . . . . 15 mm + 1 ppm RMS

## network rtk

Horizontal . . . . . 8 mm + 0.5 ppm RMS  
Vertical . . . . . 15 mm + 0.5 ppm RMS  
Initialization time<sup>5</sup> . . . . . typically <8 seconds  
Initialization reliability<sup>5</sup> . . . . . typically >99.9%

1 Optional upgrade.

2 Precision and reliability may be subject to anomalies due to multipath, obstructions, satellite geometry, and atmospheric conditions. The specifications stated recommend the use of stable mounts in an open sky view, EMI and multipath clean environment, optimal GNSS constellation configurations, along with the use of survey practices that are generally accepted for performing the highest-order surveys for the applicable application including occupation times appropriate for baseline length. Baselines longer than 30 km require precise ephemeris and occupations up to 24 hours may be required to achieve the high precision static specification.

3 Depends on SBAS system performance.

4 Network RTK PPM values are referenced to the closest physical reference station.

5 May be affected by atmospheric conditions, signal multipath, obstructions and satellite geometry. Initialization reliability is continuously monitored to ensure highest quality.

6 Receiver will operate normally to -40 °C, internal batteries are rated to -20 °C, optional internal GSM modem operates to -30 °C.

7 Tracking GPS, GLONASS and SBAS satellites. Optional upgrade required for GLONASS.

8 Varies with temperature and wireless data rate. When using a receiver and internal radio in the transmit mode, it is recommended that an external 6 Ah or higher battery is used.

9 Varies with terrain and operating conditions.

10 Bluetooth type approvals are country specific.

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PN 022543-490E (04/13)

## hardware

### physical

Dimensions (W×H) . . . . . 19 cm × 10.2 cm (7.5 in × 4.0 in), including connectors  
Weight . . . . . 1.52 kg (3.35 lb) with internal battery, internal radio with UHF antenna  
3.04 kg (6.70 lb) items above plus range pole, controller, and bracket

### Temperature<sup>6</sup>

Operating . . . . . -40 °C to +65 °C (-40 °F to +149 °F)  
Storage . . . . . -40 °C to +75 °C (-40 °F to +167 °F)

Humidity . . . . . 100%, condensing

Water/dustproof . . . . . IP67 dustproof, protected from temporary immersion to depth of 1 m (3.28 ft)

Shock and vibration . . . . . Tested and meets the following environmental standards:

Shock . . . . . Non-operating: Designed to survive a 2 m (6.6 ft) pole drop onto concrete. Operating: to 40 G, 10 msec, sawtooth

Vibration . . . . . MIL-STD-810F, FIG.514.5C-1

### electrical

- Power 11 V DC to 28 V DC external power input with over-voltage protection on Port 1 (7-pin Lemo)
- Rechargeable, removable 7.4 V, 2.6 Ah Lithium-Ion battery. Power consumption<sup>7</sup> is 3.2 W in RTK rover mode with internal radio and Bluetooth in use.
- Operating times on internal battery<sup>8</sup>:
  - 450 MHz receive only option . . . . . 5.0 hours
  - 450 MHz receive/transmit option (0.5 W) . . . . . 2.5 hours
  - Cellular receive option . . . . . 4.7 hours

### communications and data storage

- Serial: 3-wire serial (7-pin Lemo) on Port 1; full RS-232 serial on Port 2 (Dsub 9 pin)
- Radio modem: fully integrated, fully sealed internal 450 MHz receiver/transmitter option:
  - Transmit power: 0.5 W
  - Range<sup>9</sup>: 3–5 km typical / 10 km optimal
- Cellular: fully integrated, sealed internal GSM/GPRS option
- Bluetooth: fully integrated, sealed 2.4 GHz communications port (Bluetooth®)<sup>10</sup>
- External communication devices for corrections supported on Serial and Bluetooth ports
- Data storage: 11 MB internal memory, 188.6 hours of raw observables (approx. 1.4 MB/day), based on recording every 15 seconds from an average of 14 satellites

### data formats

- CMR: CMR+, CMRx input and outputs
- RTCM: RTCM 2.1, RTCM 2.3, RTCM 3.0, RTCM 3.1 input and outputs
- Other outputs: 23 NMEA outputs, GSO, RT17 and RT27 outputs, supports BINEX and smoothed carrier

### supported trimble controllers

- Trimble Slate Controller
- Optional<sup>1</sup>: Trimble TSC3 controller, Trimble CU controller, Trimble Tablet Rugged PC

### certifications

FCC Part 15 (Class B device), 22, 24, 90; CE Mark; C-Tick; 850/1900 MHz; Class 10 GSM/GPRS module; Bluetooth EPL



Specifications subject to change without notice.

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SINGAPORE



# TRIMBLE SLATE CONTROLLER

## KEY FEATURES

Familiar, **easy-to-use**, smartphone form factor

**All-in-one** device that provides both smartphone and data collection capabilities

Durable Gorilla Glass and **4.3 inch capacitive touch display**

Communication technology enables **enhanced connectivity**

**Optimized** for Trimble Access field software for survey workflow support



## A SMART MOBILE SURVEYING SOLUTION

Powerful, connected, and compact, the Trimble® Slate Controller combines the convenience and ease-of-use of a smartphone with the durability for which Trimble is known. Its slim, ergonomic design is easy to grasp and its screen provides superior sunlight readability enabling all-day use by hard-working survey professionals. Optimized for Trimble Access™ field software and the Trimble R4 GNSS receiver, the Trimble Slate Controller fully supports your everyday workflows and unique requirements.

## ONE DEVICE FOR BOTH VOICE AND SURVEYING DATA COLLECTION

With the Trimble Slate Controller, you no longer need to juggle a smartphone and a rugged computer to stay connected to the office, your clients, and even your survey equipment. Offering voice, SMS text, and 3.75G cellular data transfer capabilities on GSM cellular networks worldwide, the Trimble Slate Controller is a rugged all-in-one device that enables enhanced communication and survey workflow support in the field.

- Transfer data to and from the cloud using Wi-Fi or WWAN connections
- Connect to a Trimble VRS™ network via high speed connection capabilities
- Connect directly to, and control, the Trimble R4 GNSS receiver using the controller's integrated Bluetooth® capability
- Enhance your job documentation and point attribution by capturing geotagged, high quality, digital photos with the integrated 8 MP camera
- Navigate directly to points using the internal GPS and Compass
- Maintain voice communication with company personnel

## DESIGNED TO SUPPORT YOUR DAILY WORKFLOWS

Trimble Access field software, available on the Trimble Slate Controller, offers numerous features and capabilities to streamline the flow of everyday surveying work, such as topographic surveying, stakeout, control, and more. Streamlined workflows guide crews step-by-step through common project types and allow crews to get the job done faster with less distractions, while improving data consistency. Survey companies can also implement their unique workflows by taking advantage of the customization capabilities available in the Trimble Access Software Development Kit (SDK).

The Trimble Access Software Developer Kit provides software developers with the tools to customize and extend Trimble Access.

## YOUR MOBILE OFFICE IN THE FIELD

A 1 GHz processor and 512 MB RAM provide powerful computing capabilities that allow you to run software applications quickly and reliably.

The Trimble Slate Controller runs the Windows® Embedded Handheld 6.5 Professional Operating System and Microsoft Office® Mobile® 2010, allowing you to take advantage of mobile office applications such as Word, Excel, PowerPoint, and Outlook, all without a trip to the office.

Once complete, simply transfer the job file back to your office using the Trimble Slate Controller's integrated communications technology. The Trimble Slate Controller is ready for the obstacles that may come your way. Did the client change the deliverables and the crews are already on site? No problem...simply use the communication capabilities to download the new job files without going back to the office.

## SMARTPHONE CONVENIENCE. TRIMBLE DURABILITY

Whether on the job site, on the road, or in the office, the Trimble Slate Controller offers the convenient smartphone features you need to stay productive, informed, and in touch while its rugged design is built to withstand the most extreme environments your work requires. At 13.5 oz, its slim, ergonomic design means you can take the Trimble Slate controller anywhere.

Designed to hold up against the toughest of conditions, a 4.3 inch capacitive touch, Gorilla® glass display covers the entire front surface and provides superior sunlight readability without sacrificing durability.

The Trimble Slate Controller operates in extreme temperatures of -30 °C to +60 °C (-22 °F to +140 °F). It can also withstand a pole drop of 1.22 m (4.0 ft) onto a concrete surface.

## DEPENDABLE WHEN EVERY POINT COUNTS

The Trimble Slate Controller, partnered with Trimble Access and the Trimble R4 GNSS receiver, provides a dedicated GNSS solution that is effective for both real time and post processed GNSS surveys. Providing everything you need to perform a basic survey campaign, this straightforward solution performs under the most rigorous conditions.

Work smart with the Trimble Slate Controller, an all-in-one device for voice and surveying data collection.

\* Trimble Slate Controller is compatible with the Trimble R4 GNSS receiver only.



### STANDARD SOFTWARE

Windows Embedded Handheld 6.5 Professional Operating System including:

- Trimble SatViewer (GPS interface application)
- Trimble CellStart (WWAN configuration application)
- Microsoft Office Mobile 2010 (Word Mobile, Excel Mobile, PowerPoint Mobile, Outlook Mobile)
- Internet Explorer Mobile 6
- Microsoft My Phone with SMS Text Messaging
- Camera control application
- Flashlight mode control application
- Calculator
- Calendar
- Microsoft Pictures & Videos
- Windows Media Player
- Windows Live Messenger
- Microsoft Task Manager & Notes
- Adobe Reader LE 2.5

Operating System Language Support: Chinese (Simplified), English, French, German, Italian, Japanese, Korean, Portuguese, Russian or Spanish

### STANDARD ACCESSORIES

- International AC charging kit
- USB cable
- Wrist strap
- Capacitive stylus with tether
- Ultra clear screen protectors (qty 2) kit
- Quick Start Guide

### OPTIONAL ACCESSORIES

- 9-pin serial adapter
- USB host adapter
- External battery pack
- Port cover
- Ultra clear screen protectors (qty 10) kit
- Anti-reflective screen protectors (qty 2) kit
- Vehicle charging kit
- Capacitive touchscreen gloves
- Trimble headset
- External GPS antenna

All standard accessories are also available to order separately.

### PHYSICAL SPECIFICATIONS

Size: 15.5 cm x 8.2 cm x 2.5 cm (6.1 in x 3.2 in x .9 in)  
Weight: 0.4 kg (13.5 oz), including battery

### CERTIFICATIONS

FCC, CE, R&TTE, IC (Canada), C-tick, GCF compliant, RoHS compliant, Section 508 compliant, PTCRB, SAR, AT&T network compatible, Wi-Fi Alliance certified, CCX, USB 2.0 Full Speed, MIL-STD-810G, IP65/IP68, MIL-STD-461E.

### ENVIRONMENTAL SPECIFICATIONS

Temperature:

- Operating: -30 °C to 60 °C (-22 °F to 144 °F)
- Storage: -40 °C to 70 °C (-40 °F to 158 °F)
- Temperature shock: Cycles between -30 °C and 60 °C (-22 °F and 144 °F), MIL-STD-810G, Method 503.5, Procedure I-C
- Water: Survives immersion at 1 m (3.3 ft) for two hours, IEC-60529 IPx8
- Dust: Protected against dust, IEC-60529 IP6x, dust chamber with under-pressure
- Drops: Survives multiple drops of 1.22 m (4 ft), MIL-STD-810G, Method 516.6, Procedure IV, Transit Drop
- Humidity: 90% relative humidity with temperatures between 30 °C and 60 °C (22 °F and 144 °F), MIL-STD-810G, Method 507.5, Procedure II
- Altitude: 4,572 m (15,000 ft) at 23 °C (73 °F) to 12,192 m (40,000 ft) at -30 °C (-22 °F), MIL-STD-810G, Method 500.5, Procedure I, II & III
- Vibration: General minimum integrity and loose cargo tests, MILSTD-810G, Method 514.6, Procedure I & II, Category 5
- Solar Exposure: Survives prolonged UVB exposure, MIL-STD-810G, Method 505.5, Procedure II
- Chemical Exposure: Resistant to mild alkaline and acid cleaning solutions, fuel hydrocarbons, alcohols and common vehicle and factory machine lubricants

### ELECTRICAL SPECIFICATIONS

- Processor: 1 GHz, Texas Instruments DM3730
- Memory: 512 MB
- Storage: 16 GB SSD
- Expansion: MicroSD memory card slot (supports SDHC up to 32 GB, SIM card slot)
- Display:
  - 10.9 cm (4.3 in), 480 x 800 pixel, WVGA TFT
  - Sunlight-readable Gorilla Glass display
  - Light sensor to auto-adjust display brightness
  - Capacitive multi-touch interface
- Battery: 3.7 V, 3.3 Ah, 12.2 Wh, Lithium-ion polymer
- I/O: Custom Port that supports USB 2.0 Host, USB Client, 9-pin Serial and 5.6 V (5.0 V to 5.9 V) DC input power
- Audio: Integrated speaker and microphone with 3.5mm audio jack
- Wireless:
  - Integrated 3.75G cellular data, text and voice capability
  - Bluetooth 2.1 +EDR;
  - Wi-Fi 802.11 b/g/n
  - WWAN radios: UMTS / HSPA+, GSM / GPRS/ EDGE, UMTS Bands (WCDMA/FDD): 800 AWS, 850 AWS, 1900 AWS and 2100 MHz, GSM Bands: 850 MHz, 900 MHz, 1800 MHz, 1900 MHz
- Camera/GPS/compass/accelerometer:
  - 8 MP camera with geo-tagging and dual LED flash
  - GPS receiver: 2-4 m accuracy with WAAS/SBAS correction; MCX port for optional external antenna
  - Integrated electronic compass and accelerometer

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