University of Southern Queensland

Faculty of Health, Engineering and Sciences

Assessment of Automatic Target Recognition Against Manual Aiming in Conventional Establishment of Survey Control

A dissertation submitted by

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Abstract

The purpose of this project is to definitively test the aiming precision of automatic target recognition systems and the manual sighting of surveyor. To date there has been no scientific evidence found to justify the use of one method over another. This experiment aims to proves which method is more accurate and would be better suited for the establishment of survey control using a conventional total station.

The project tests the different methods of aiming to a target under various conditions, including the use of an assortment of simulated obstructions to replicate conditions often encountered during day-to-day field operations by surveyors using conventional total stations during the establishment of survey control. The project further analyses these results by the variation of observed horizontal and vertical angles from each experimental scenario. These results provided the evidence for a definitive answer as to whether the use of automatic target recognition or manual sighting is better suited for survey tasks where optimum accuracy is needed.

This project scientifically established that Trimble FineLock was the most accurate method of aiming closely followed by Manual Aiming the total station. Both of these methods produced significantly better results than what was attainable with Trimble AutoLock and should be used where possible.

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Limitations of Use

Certification

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Signed:

[redacted]

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Glossary of terms

AL	AutoLock
ATR	Automatic Target Recognition
CCD	Charge-coupled Device
CL	Confidence Level
CMOS	Complementary Metal-oxide Semiconductor
FL	FineLock
HA	Horizontal Angle
ICSM	Intergovernmental Committee on Survey and Mapping
S6	Trimble S6 3" Total Station
S9	Trimble S9 1" Total Station
SP1	Special Publication 1
SWMS	Safe Work Method Statement
VA	Vertical Angle

1. Introduction

1.1 Introduction to Automatic Target Recognition

In the surveying industry, there are often a number of different methods which allow for the achievement of a satisfactory result for a particular task at hand. Experienced surveyors generally have their preferred method of practice which they use to carry out the particular task and they repeat this same method across every job. Their method of practice is usually a result of implementing their work in the way they were trained to do the task. The downfall to continuing to practice methods of surveying based on this, is the surveyor may not have determined if a particular practice is the most accurate method for the task. Additionally, if the surveyor trains future cadets with these methods, they may possibly be neglecting educating cadets in all methods, practices and identifying the suitability of methods to the individual task at hand.

Often the methodologies used to complete certain surveying tasks divides surveyors. Differences can be seen between the older generation of surveyors compared to the younger generation, and between civil construction surveyors, engineering surveyors and cadastral surveyors. Surveyors constantly debate and make claims against each other, often without any solid unbiased results or testing to validate their claims.

The surveying method this project investigates and reports on, is whether using the automatic target recognition aiming method or the manually sighting method through the eye piece of the instrument is the more accurate type of observation technique. The option to use these methods for the establishment of survey control while using a conventional total station divides the opinion of surveyors throughout the industry and to date research has not found any substantial documented evidence to prove whether an average surveyor can manually sight a target better than a standard total station utilizing automatic target recognition.

All surveyors understand that for most projects either method will 'get the job done' but the purpose of this research project is to identify which method is more accurate at observing a target, human or machine. Some surveyors hold a lot of doubt while using automatic target recognition technology for control surveys or other high accuracy required surveys.

For ease of clarification in this project there are two common scenarios, scenario 'A' - manual sighting, and scenario 'B' – the use of automatic target recognition. In scenario 'A' manual sighting is used to try and prevent potential errors from obstructions to the line of sight and heat shimmer. Often long traverse leg lengths are avoided because they could be affected by heat shimmer or poor visibility due to the size of the small survey target over larger distances. In Scenario 'B' the survey is completed with ATR, relying on the technology to find the target and lock onto it without confirming if it is visible through the eye piece, or checking for obstructions, or sources of possible error such as heat shimmer. It is often argued that scenario 'B' can traverse further with less traverse legs, reducing the number of setups and therefore reducing the possible sources of error. To accomplish fewer traverse legs, each observation is extended in length. Often these distances are extended so much scenario 'A' would become difficult to implement, as it becomes increasing difficult to view the target through the eye piece due to loss of image quality.

1.2 Research Focus

To be able to answer the questions outlined above this research paper seeks to research, test and evaluate the different methods available for aiming a total station at a target for use in establishing survey control in various site conditions.

1.3 Background

Automatic target recognition has been an option offered by most major theodolite / total stations manufacturers for many years with the first application of the technology over 30 years ago. Before the invention of automatic target recognition systems surveyors would have to manually aim the instrument to a reflective prism for every observation. This was a time-consuming task and had potential for numerus errors depending on the skill levels and care taken by the surveyor. Often surveyors would rush sighting the target during mundane tasks like a detail survey requiring hundreds of points to be located, but while traversing or establishing control more care would often be taken to ensure the accuracy of the survey.

The use of automatic target recognition technology reduced the number of potential errors and improved sighting accuracy for these mundane survey tasks while drastically improving the time taken to complete surveys. However, it took some time before surveyors became more comfortable and started relying on this technology to complete control surveys, with some surveyors still not trusting of the use of this technology for the establishment of survey control.

All current models of total stations manufactured by major companies come with this feature as standard. These companies all name the technology slightly different, for example Automatic Target Recognition, AutoLock/FineLock, Focusing System, Auto Pointing & X-TRAC are all systems provided by the manufacturers Leica, Trimble, Nikon, Sokkia & Topcon respectively. Each of the manufacturer's technology utilises similar operating principles. Trimble FineLock however is a newer system developed specifically for the acquisition of static targets. Trimble states the precision of this system is much better than the older AutoLock system.

1.4 Aim and Objectives

The aim of this research project is to determine which of the different methods available for aiming a robotic total station achieves the most accurate sighting to a standard reflective survey target that would normally be used in establishing survey control.

Automatic target recognition and manually sighting each have their limitations. Some of these include partial target obstructions, reflective interference and the heat shimmer effect, that influence each method of aiming by varying amounts over different distances. Any of these limitations could regularly be present during field observations and will contribute to diminished accuracy of survey results.

To validate and quantitate this claim, this research project will test three different methods of aiming to a reflective survey target: Manual sighting, AutoLock and FineLock. Each of the three methods will be tested under a number of various planned field conditions to simulate the different styles and severity of interference a surveyor could normally encounter during the observation of control points. The results collected during the tests will be used to analyse and establish any patterns in the variability of the horizontal and vertical angles recorded during each set of observations to determine what aiming method provided the most accurate result under each set of field conditions.

The findings from the analysis will be the basis for the creation a set of preferred aiming techniques that will be produced to assist surveyors when establishing survey control. This will not only assist surveyors in choosing the optimum technique for the task at hand, it will also shed some light on the possibility of increased errors when utilizing each aiming method under various conditions.

1.5 Outcomes and Benefits

Successful completion of the project will deliver a definitive answer as to which is the most precise and reliable method of aiming to a prism using a total station in each condition. After reviewing each scenario, the benefit of knowing the most precise method of aiming will be identified. This will give surveyors well-tested, unbiased and researched evidence along with advice that they can use while undertaking traverse and control networks in the future to optimize the accuracy of the project at hand.

1.6 Organisation of Dissertation

This dissertation has been structured in chapters for each relevant section of the research project. A list of each of these chapters along with their purpose has been outlined below.

Chapter 1 – Introduction. This chapter outlines the purpose of the research project, its aim, limitations, and dissertation structure.

Chapter 2 - Literature review. The review outlines each topic researched and how this information is relevant to automatic target recognition systems. This chapter is used to identify areas that need to be further researched and plan approaches to the experiments.

Chapter 3 - Research Methodology. This chapter documents the study area along with the project plan. It outlines the methods used for data capture, storage and result analysis.

Chapter 4 – Results. This chapter contains all the results from each experiment and all the calculations based from this data. The Raw data along with all calculations are tabulated and graphed to depict the results observed.

Chapter 5 – Discussion. The analysis of the results from each experimental condition and how the results can be used to establish the most accurate method of aiming are objectively discussed.

Chapter 6 – Conclusion. The review the research, results and discussion are summarised to identify if the aim and objectives of the project have been achieved.

Chapter 7 – Recommendations. This chapter outlines the recommended procedures that should be used for aiming a total station during the establishment of survey control. Recommendations for future research that could further the development of these survey practices are also included in this chapter.

Chapter 8 – References. A list of any existing material that has been relied upon during the research project is noted for reference.

1.7 Conclusion

Automatic Target Recognition systems are used daily by surveyors for various tasks often without them fully understanding the accuracy's or limitation of the technology. The limitation of this technology may impede the accuracy of control establishment survey when compared to manually aiming the total station. This research project aims to investigate, test and report on ATR technology, manual aiming and how the two methods perform against each other.

2. Literature Review

2.1 Introduction

This research paper assesses the accuracy and precision of 3 methods of aiming a total station to a reflective survey target. Atmospheric conditions, on-line obstructions, errors in software, errors in the instrument's sensors all affect the ability to aim to a target accurately. These possible sources of error need to be researched and understood in order to identify them, quantify and assess their affect, as well as try to minimise their impact. Hence, the research contained in the following sub-chapters.

2.2 Establishment of Survey Control

The accurate measurement of angles is crucial to ensuring a survey task is undertaken correctly, without mistake or misrepresentation of data. This becomes more important when undertaking a survey traverse as angular error can easily be propagated through each leg of a survey traverse. For this reason, surveyors take redundant observations, including observing a target from multiple locations and measuring cross braces to enhance the accuracy of the control network.

The prescribed measuring accuracy of a surveying instrument is often stated in the model of the instrument, for example a Trimble S6 3". This 3" is the accuracy at which the instrument can read angles, but this is only the accuracy for the measurement of the instrument's internal angles plates. Possible error of the chosen aiming method still needs to be taken into consideration, along with centring errors from the surveyor's setup and the build quality of the reflective prism. While taking all these possible errors into account, the instrument may not be aimed at the target correctly because of some type of interference of the beam received by the CMOS sensor. This research project does not take into account centring errors as it is investigating the deviation of observations to the survey prism itself to avoid obtaining any extra errors that don't relate to the measurement accuracy.

This research project endeavours to find the most accurate form of aiming a total station to aid in the reduction of total possible errors during the establishment of survey control. By achieving this, surveyors could have a clear understanding of how automatic recognition works, its capabilities and be able to make a judgment as to whether it would be acceptable to use for the task. Automatic target recognition works similarly between all the different manufacturers. However, the processes undertaken by both the surveying hardware and software that allow for pointing of a total station aren't clearly described by all manufacturers for their brand of instrument.

2.3 Automatic Target Recognition Technology

Automatic target recognition technology allows a surveyor to point the total station to a prism without looking through the eye piece of the telescope. The surveyor only has to roughly position the total station in the vicinity of the prism then the instrument takes over.

Automatic target recognition uses an infrared laser beam that is invisible to the human eye. The beam is transmitted from the total station coaxially from the optics and reflected back by any standard surveying prism. Standard reflective prisms used in surveying take light received and reflect it, emitting it back parallel to the same direction it was input. The returned infrared laser light is captured by the total station using an internal high-resolution complementary metal oxide semiconductor (CMOS) sensor. The intensity and laser beam characteristics of this reflected light are computed in both the horizontal and vertical plane with respect to the CMOS camera sensor centre. These offsets are then used to guide the controlling servo motors on each axis of the total station, so the cross hairs are directly aimed at the centre of the strongest return signal being the centre of the reflective prism target. To minimise aiming time, the axes of the instrument are only positioned within a 5mgon range of the actual target and the remaining offsets are then mathematically applied to the Hz and V angles (Leica 2008).

Both Complementary Metal Oxide Semiconductor (CMOS) sensors and Charge Coupled Device (CCD) in older total stations are used to convert light to electrical signals. This photoelectric technology is similar to the way a standard digital camera works. The electrical signals produced are then used by the operating software to aim the total station at the computed target location. CMOS sensors are used in most new total stations over CCD sensors because the CMOS sensors have clearer image capture capabilities even with the presence of bright background sunlight. They also have a faster image processing time (Leica, 2008). The CMOS sensors have the ability to filter out high levels of noise, are cheaper to purchase, use less power and produce less heat then the CCD sensors.

Figure 2.1, Automatic Target Recognition Diagram

Below is an image of a CMOS sensor the multi coloured area in the centre receives the infrared laser beam and converts it to electrical signals that are output through the series of electrical terminals around the sensor chip. Each terminal electrifies when the laser contacts the adjoining zone in an X-Y arrangement.

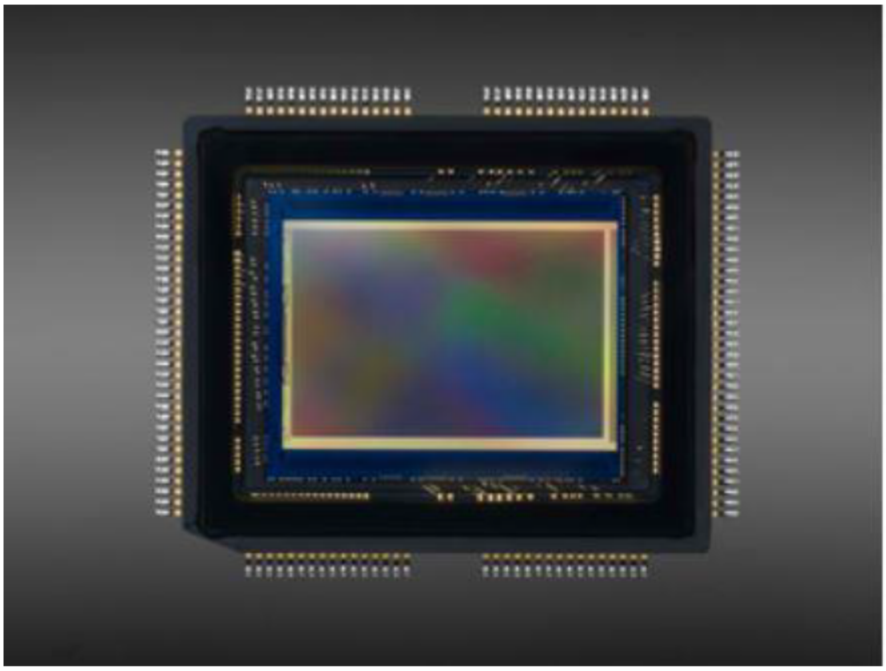

Figure 2.2, Example of CMOS Sensor - sourced:
https://imaging.nikon.com/lineup/coolpix/a/a/features02.htm

Most manufacturers have limited information available that explains how their automatic target recognition technology operates. Leica have published a white paper for their ATR technology. This white paper has provided the technical details required to understand the process of the ATR system. The lack of this information could potentially be the cause of limitations with the understanding of surveyors with this technology. It should be noted that this project is limited to the use of non-Leica total stations during the testing phase, and it cannot be confirmed if the Trimble total stations to be tested use commensurate technology to that of the Leica automatic target recognition.

To optimize the clarity of the infrared laser beam received back by the CMOS sensor it is necessary to ensure all total stations lenses are clean and in a good, unscratched operating condition. The face of a high-quality reflective survey prism should be cleaned and without scratches. It's also important that the reflective material at the rear of the prism is in good condition for good light transfer.

2.4 Manufacturers ATR Specifications

The precision of automatic target recognition technology is often stated on the data sheet provided by the instrument manufacture. The data sheet for the Trimble S6 Total Station lists an AutoLock pointing precision at 2mm at 200m at one standard deviation (1σ) this equates to a confidence level of 68% (Trimble 2013). This means that 68% of the time any angular observation recorded to a prism will be less then 2mm from the mean of all observations at 200m. In most cases we can assume that this possible error multiplied by 1.96 brings us to the 95% confidence level, therefore a precision of +/- 3.92mm at 200m at the 95% confidence level. The 95% confidence interval is what most survey accuracies and legislation are quoted to however instrument manufactures often state the precision of their instrumentation at the 68% confidence interval.

TRIMBLE S6
TOTAL STATION

ROBOTIC SURVEYING

Autolock and Robotic Range[2]

Passive prisms	500 m–700 m (1,640–2,297 ft)
Trimble MultiTrack Target	800 m (2,625 ft)

Autolock pointing precision at 200 m (656 ft) (Standard deviation)[2]

Passive prisms	<2 mm (0.007 ft)
Trimble MultiTrack Target	<2 mm (0.007 ft)
Shortest search distance	0.2 m (0.65 ft)
Type of radio internal/external	2.4 GHz frequency-hopping, spread-sprectrum radios
Search time (typical)[6]	2–10 sec

Figure 2.3, Trimble S6 AutoLock Precision – sourced:
http://trl.trimble.com/docushare/dsweb/Get/Document-208580/022543-098L_TrimbleS6_DS_0613_LR.pdf

1 Standard clear: No haze. Overcast or moderate sunlight with very light heat shimmer.
2 Range and accuracy depend on atmospheric conditions, size of prisms and background radiation.
3 Kodak Gray Card, Catalog number E1527795.
4 The capacity in –20 °C (–5 °F) is 75% of the capacity at +20 °C (68 °F).
5 Bluetooth type approvals are country specific. Contact your local Trimble Authorized Distribution Partner for more information.
6 Dependent on selected size of search window.
7 Solution acquisition time is dependent upon solution geometry and GPS position quality.

Figure 2.4, Trimble S6 AutoLock Precision Foot Note – sourced:
http://trl.trimble.com/docushare/dsweb/Get/Document-208580/022543-98L_TrimbleS6_DS_0613_LR.pdf

The data sheet for the Trimble S9 Total Station also lists an AutoLock pointing precision of 2mm at 200m at one standard deviation, this equates to a confidence level of 68%. The same data sheet for the S9 also lists a FineLock pointing precision of 1mm at 300m at one standard deviation (confidence level of 68%) (Trimble 2018).

Trimble S9/S9 HP TOTAL STATION

AUTOLOCK AND ROBOTIC SURVEYING

Passive prisms	500 m–700 m (1,640–2,297 ft)
Trimble MultiTrack Target	800 m (2,625 ft)
Trimble ActiveTrack 360 Target (DR Plus EDM)	500 m (1,640 ft)
Trimble ActiveTrack 360 Target (DR HP EDM)	100 m (328 ft)
Autolock pointing precision at 200 m (656 ft) (Standard deviation)[3]	
Passive prisms	<2 mm (0.007 ft)
Trimble MultiTrack Target	<2 mm (0.007 ft)
Trimble ActiveTrack 360 Target	<2 mm (0.007 ft)
Shortest search distance	0.2 m (0.65 ft)
Type of radio internal/external	2.4 GHz frequency-hopping, spread-sprectrum radios
Search time (typical)[7]	2–10 sec

FINELOCK

FineLock pointing precision at 300 m (980 ft) (standard deviation)[3]	<1 mm (0.003 ft)
Range to passive prisms (min–max)[3]	20 m–700 m (64 ft–2,297 ft)
Minimum spacing between prisms at 200 m (656 ft)	0.8 m (2.625 ft)

Figure 2.5, Trimble S9 ATR Precision – sourced:
https://drive.google.com/file/d/0B1S3SpCN8_0IeDFzWEozVlVvd0U/view

1 Standard deviation according to ISO17123-4.
2 Standard clear: No haze. Overcast or moderate sunlight with very light heat shimmer.
3 Range and accuracy depend on atmospheric conditions, size of prisms and background radiation.
4 Kodak Gray Card, Catalog number E1527795.
5 The capacity in –20 °C (–5 °F) is 75% of the capacity at +20 °C (68 °F).
6 Bluetooth type approvals are country specific. Contact your local Trimble Authorized Distribution Partner for more information.
7 Dependent on selected size of search window.
8 Long Range FineLock can be used with standard FineLock from 20 m.
9 Solution acquisition time is dependent upon solution geometry and GPS position quality.
10 Functionality and availability dependent on region.

Figure 2.6, Trimble S9 ATR Precision Foot Note – sourced:
https://drive.google.com/file/d/0B1S3SpCN8_0IeDFzWEozVlVvd0U/view

To bring the manufactures precision specifications of both AutoLock and FineLock for these two instruments into comparable values we can convert all the stated values to the precision expected at 300m at the 95% confidence interval.

AutoLock at 300m:

300m/200m x 2mm = 3mm

3mm at 68% x 1.96 = 5.88mm at 95%

FineLock at 300m:

1mm at 68% x 1.96 = 1.96mm at 95%

Therefore, we can assume that the following precisions apply to the instruments in each operating mode.

Trimble S6 AutoLock = +/- 5.88mm of pointing error at 300m (95%CL)

Trimble S9 AutoLock = +/- 5.88mm of pointing error at 300m (95%CL)

Trimble S9 FineLock = +/- 1.96mm of pointing error at 300m (95%CL)

To test these assumptions a series of observations will be made under the standard conditions specified in the Trimble data sheets at a range of 300m with AutoLock, FineLock and manual aiming. It is expected the instrument will automatically aim and achieve the accuracies assumed above. From experience manual aiming is expected to achieve a more accurate result then AutoLock. However manual aiming is unlikely to obtain the stated accuracies of the FineLock technology. A statistical analysis of the results will be undertaken to evaluate the results of each method and any differences between the range and standard deviation from the mean of each sample methods. Observations will also be conducted at various different ranges to test how the distance from instrument to the reflector prism may affect the results.

2.5 Sources of Interference

The infrared laser beam emitted from a total station may be interfered by numerous different sources along its path from the instrument to the reflective prism and back to the instrument. These sources can be categorized into two different types: sources that modify the light and sources that block or restrict the light.

One of the most common sources of interference that would modify the light beam is called heat shimmer or heat haze. This mirage effect is caused by the way light travels through the air layers at varying temperatures. As the different layers of air temperature mix, the way light reacts within them does as well, causing the light path to be refracted through air layers and distorted, extended or shifted. Often this can be visually seen as a blurry image on the horizon of a hot day or the blurry steam type phenomena that can been seen above a hot bitumen road.

The heat shimmer effect can drastically alter the signal return to the total station by creating a distorted image at the internal CMOS sensor resulting in an incorrect computation and errored aiming of the total station. These phenomena can also have a significant effect on the Electronic Distance Measurement EDM of the instrument as the time taken for the light to return to the instrument would increase due to the longer flight path.

Heat Shimmer is often encountered in these common survey scenarios:
Observations over long survey lines (approximately 200m); observations across sealed surfaces (for example roadways or concrete); observations over large bodies of water; and even observations taken through the heated air above earthmoving machinery or through their exhaust gasses. Atmospheric conditions often affect the magnitude of beam distortion. Increases in air pressure, humidity or temperature all add to the possibility of these beam distortions causing a reduction in accuracy. To analyse the interference caused by the heat shimmer effect an experimental environment will be created to simulate heat shimmer at low, medium and high levels by making large numbers of observations a fixed target and analysing the deviation of the results.

Figure 2.7, Example of the Effect of Heat Shimmer – sourced:
https://www.bbc.com/news/magazine-23341698

Another source of error that would modify the light beam returned to the total station is reflective objects that are near the path of the light beam. For example, taking a measurement to a survey prism located in front of a glass window shopfront or possibly taking a measurement past a reflective street sign.

The extra reflective surfaces surrounding the line of the observation could reflect the light beam at a slightly different angle to the light being reflected from the survey prism. The total station then receiving two different reflective light sources would aim to the centre of the light cluster that may now not be the true sighting of the prism. To test the magnitude of this possible effect, observations will be made with reflective objects places placed near the light of sight, very close to the line of sight and behind the line of site. The deviation of the results will indicate the effect this may have on aiming accuracy under various test conditions.

Sources of interference that block or restrict light simply cover or continually interrupt part of the light beam transmitted from the instrument or on its return path, or often even both paths. This restricts the view of the CMOS censor and doesn't allow it to see a true reflection of the reflective prism, as a result an incorrect computation is calculated to aim the instrument. This type of obstruction interference along the line of sight is often caused by factors including tall grass, tree branches and leaves, measuring through wire fences and grazing rays (where light beam grazes past the edge of a tree, retaining wall or other solid object).

To test the effect of grazing rays during the experiment common items that would normally be encountered will be placed partially in front of the survey prism blocking its path, such as a tree trunk or retaining wall edge. To test the continually interrupted interference, tree branches with leaves and long grass will be placed along the light of sight. These datasets will be compared to the control test to investigate variances.

2.6 Instrument Calibration

To ensure each of the instruments to be utilised during the course of the experiment are in optimal working condition the instrument's compensator, collimation and AutoLock collimation will be checked and adjusted prior to the testing.

The compensator adjustment in the instrument allows for the electronic level of the instrument to be calibrated. When an instrument has been levelled then rotated 180° the numerical values shown on the level screen should remain the same with just the + and – symbols swapping for each axis. If this is not the case the compensator is in need of calibration and the vertical angle readings could be false as VA 90° may not be set as perpendicular to gravity. Each of the instruments' routine for the calibration of the compensator automatically balances the optics of the instrument then proceeds to take level readings at a series of equal horizontal angles spacings around the full 360° sweep of the HA. These readings are used to calculate the true levelness of the instrument, calibrate the electronic bubble and set VA 90°.

During a survey most measurements are taken with only one face, so it is crucial that the instrument be fully calibrated. When establishing surveying control, the proper technique of measuring multiple rounds of both face left and face right observations as can be seen in the following observation technique table published by The Intergovernmental Committee on Surveying and Mapping (ICSM). These observations allow the survey software to average out all of the observations to negate collimation error.

Collimation and AutoLock Collimation is not as crucial for this experiment as we will be sighting the same point over and over in one face, measuring bearings not angles, but for completeness these are calibrated by measuring a series of face left and face right observations as described in the adjustment section of the Trimble operator's manual for the instrument (Trimble S Series Total Station User Guide 2011, pp. 55-67).

The Intergovernmental Committee on Surveying and Mapping (ICSM) is the governing body for surveying and mapping issues across Australia and New Zealand. ICSM created a set of standards to be used within the surveying industry for various tasks. The ICSM 'Guideline for Conventional Traverse Surveys – Special Publication 1' v2.1 (2014) outlines the number of rounds needed to establish survey control to various ranges of precision. The requirement for a Survey Uncertainty (SU) <2mm is 5 rounds of observations, that equals 10 observations to the target. For the purpose of this experiment it is proposed to double the number of observations in an attempt to establish any trends in angle deviations.

Table 2.1, The ICSM 'Guideline for Conventional Traverse Surveys' Special Publication 1 - sourced:
https://www.icsm.gov.au/sites/default/files/2018-02/Guideline-for-Conventional-Traverse-Surveys_v2.1.pdf

SU: < 2 mm **RU: < 2 mm or < 10 ppm**	**SU: < 10 mm** **RU: < 10 mm or <30 ppm**	**SU: < 30 mm** **RU: < 30 mm or <100 ppm**
Survey specific:		
Traditional survey traverse techniques – face left/face right, back sight/fore sight.		
Level instrument and targets directly over survey control marks.		
Height of instrument and targets measured.		
Collimation test to be performed:		
Daily	Weekly	
Number of rounds face left/face right:		
5	3	2
Residual from mean of any angle should not exceed:		
5"	10"	20"
Minimum ground clearance:		
1.0 metre	0.5 metre	
Atmospheric corrections:		
Atmospherics recorded at 1 hour intervals or pronounced changes in conditions.		N/A
Atmospherics either entered into instrument or applied in processing stages.		N/A

2.7 Knowledge Gap

Automatic Target Recognition has often been a debated talking point for many surveyors and has even been the topic of some research papers. However, these research papers and reports only investigate and discuss the accuracies between the various prism types used, or the effect of various weather and site conditions on the precision of the automatic target recognition system itself. No research or information was able to be found that compares the precision of manually sighting a target and pointing to a target using automatic target recognition technology.

The ICSM 'Guideline for Conventional Traverse Surveys – Special Publication 1' Version 2.1 dated September 2014 makes note that 'EDM Automatic Target Recognition (ATR) functionality acceptable'.

The inclusion of this ATR note in the table poses the question whether there may have been some doubt if it was suitable for the use of establishing survey control. The table below extracted from the ICSM publication indicates that Automatic Target Recognition (ATR) functionality is acceptable for the use of Electronic Distance Measurement (EDM). The table makes no reference to the aiming accuracy of ATR, or if it's acceptable for aiming the survey instrument. It is assumed that ATR is only acceptable for the use of electronic distance measurement not angular measurements.

Table 2.2, The ICSM 'Guideline for Conventional Traverse Surveys' Special Publication 1 - sourced:
https://www.icsm.gov.au/sites/default/files/2018-02/Guideline-for-Conventional-Traverse-Surveys_v2.1.pdf

SU: < 2 mm **RU: < 2 mm or < 10 ppm**	**SU: < 10 mm** **RU: < 10 mm or <30 ppm**	**SU: < 30 mm** **RU: < 30 mm or <100 ppm**
EDM distance measuring accuracy:		
± 1 mm + 1.5 ppm	± 3 mm + 3 ppm	± 5 mm + 5 ppm
Angle measuring accuracy:		
1"	5"	10"
Instrument specific:		
EDM instrument calibrated to national standard of length annually		
Instrument corrections applied (index and scale corrections)		
Reflector additive constant applied		
Reflectorless EDM should not be used to measure to survey control marks		
EDM Automatic Target Recognition (ATR) functionality acceptable		
1st velocity atmospheric correction applied:		
Yes		N/A
Atmospheric measurement device accuracy:		
T = 1°C, P = 1 mb, H = 2%		N/A
Prism:		
Precision prism, centring accuracy 0.5 mm	Circular prism, centring accuracy 1 mm	Prism, centring accuracy 2 mm
Tribrach and carrier:		
Precision carrier with optical plummet, plummet accuracy 0.5 mm at 1.5 metre	Tribrach with optical plummet, or laser plummet	
Tripod:		
Heavy duty, wooden, good condition	Good condition	

Some of the testing procedures found in research papers are very similar to the testing procedures envisioned at the start of this project. Throughout these papers, researchers tested the accuracy of different styles and models of reflective survey prisms, observing distinct traits between them. One of the papers also included testing procedures that utilised artificially created obstructions that are commonly encountered daily within the surveying industry to try and obstruct or modify the infrared light from the instrument.

The clear and successful results that these papers were able to obtain confirms that the outlined experiment methodology for this project will provide clear unambiguous results that can be studied to determine trends in the data.

The 2016 paper by Lackner & Lienhard investigated the effect various reflective prisms had on the horizontal angle measurements recorded by the total station. The prisms were orientated directly at the total station then rotated to various positions to observe the effect on observations while the prism was miss aligned. The results show as a circular prism was rotated away from the survey line the Horizontal Angle (HA) observations increased. This effect on HA had the same magnitude if the prism was rotated clockwise or any clockwise by the same amount, just the direction of HA deviation changed.
This project will investigate this scenario to confirm the theory and prove that the miss alignment of the prism wouldn't influence the results obtained from manually aiming the total station.

McDonald (2011) reported on the effect of target orientation and target tilt. This was investigated in terms of distance error from the EDM and horizontal angle offset error. Although his work was targeted toward the testing of 360-degree prisms one of the test rigs was a circular traverse prism. This indicated fluctuation as it was rotated from the line of the instrument. This theory is similar to that of Lackner & Lienhard as mentioned above.

Jones (2010) investigated the effects of obstructions along the line of survey. Simulated obstructions were placed between the survey prism and a total station setup on a concrete survey pillar for stability. The instrument was initial orientated by the average of 10 observations to a backsight used to set the instrument to a HA 0 Degrees. Each of the test conditions where then surveyed by observing 10 readings through each obstruction. This data was then analysed by investigating the maximum deflection of the HA and VA from the backsight. During the course of this project all observations will also be made from a concrete survey pillar to ensure instrument stability. Observations will be investigated by calculation of the standard deviation of the sample observations mean. This avoids any error with the initial setup of the instrument orientation. Furthermore, all results will be calculated to the 95% confidence interval and displayed in mm at the specified range too easy in interpretation.

2.8 Conclusion

From the research it is noted that physical obstructions, atmospheric conditions, illumination and length of observation may affect the survey observation and aiming accuracy. These effects need to be considered when developing a method of assessing the sighting accuracies of various methods of aiming a total station. Although some research has been performed on the effects of these sources of interference when using automatic target recognition systems, there is a gap in the existing research as to whether these sources of interference effect manual observations, and if so to what magnitude.

3. Research Methodology

3.1 Introduction

To investigate which method of aiming a total station is most accurate a series of observations will be made from a total station to a standard circular traverse prism. Experimental sets of observations will be recorded, each with a different obstruction or atmospheric conditions. During each set of observations an instrument will be aimed to a target using 5 different methods. It is crucial to reliably capture observations from the total stations while minimizing any sources of possible error. To accomplish this a stable mounting base to needs to be used to avoid any slight movement or vibration the total station may encounter during experimental observations.

3.2 Testing Location

A suitable test location has been found at the Springfield Rise Estate QLD. The experiment site is situated on the outskirts of a new housing development where concrete survey pillars have been installed at the locations indicated by the red dots 471m apart from one another. These concrete pillars allow for a number of simulated survey environments to be tested as they adjoin an array of natural vegetation, sealed roadways and housing development.

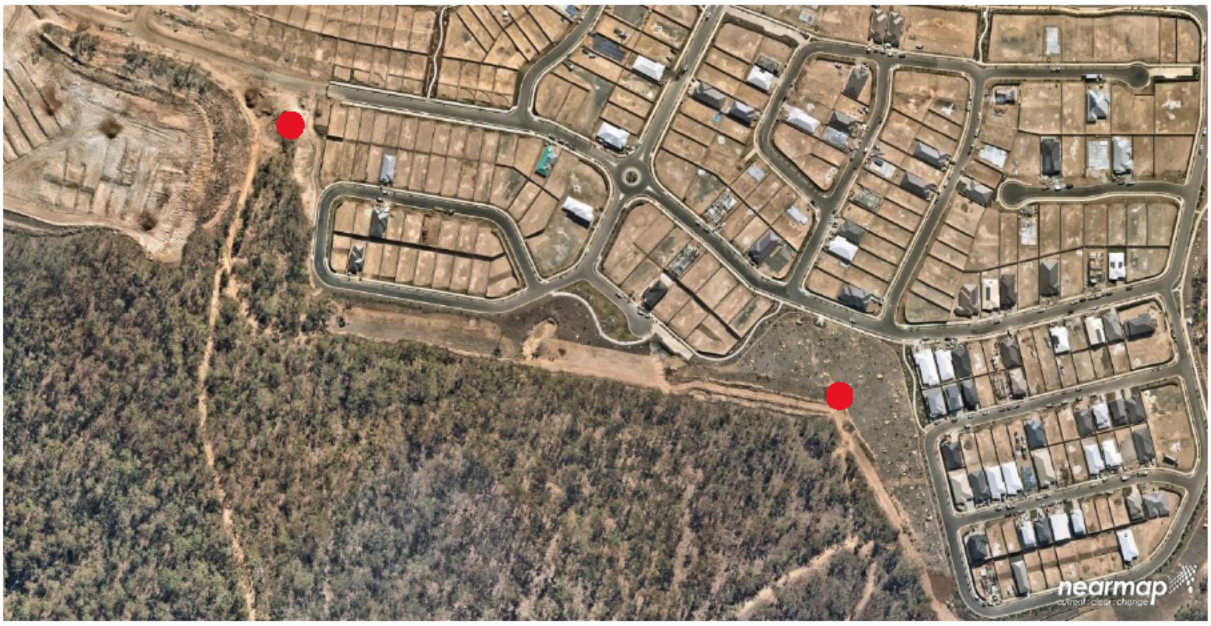

Figure 3.1, Nearmap Ariel Photograph of Test Site – sourced:
https://maps.au.nearmap.com/?ll=27.694182043245117,152.89322555466757&z=19&t=k

To ensure the experimental conditions are as constant as possible each method of aiming will be tested directly after one another. This will mitigate the risk of changing weather conditions or physical conditions between observations sets as much as possible.

3.3 Collection of Data – Testing Procedure

To test the aiming precision of each method it is proposed observations will be made between a series of stable survey pillars at various distances, height differences, temperatures and surrounding conditions, for example vegetation along the survey line, grazing rays, rainfall, dusty conditions and heat shimmer.

The following is a set of base procedures that will be followed for each variation of the experimental conditions to be tested:

- Testing conditions to be noted.
  (Length, Slope, Obstructions, Visibility, Instrumentation, Measurement time)
- All instrumentation is to be in a clean, calibrated and in operatable condition.
- A reflective traverse prism target is to be set up on a concrete pillar or stable tripod.
- A new Trimble job file created to electronically store observations.
- The Trimble S6 is to be setup on a concrete pillar to insure instrument stability.
- The Instrument is manually aimed to the target and set to HA 0°00′30″
  (This observation will not affect the results, is merely ease future calculations).
- 20 observations will be made using AutoLock
- 20 observations will be made using Manual sighting
  (Instrument is to be un-aimed and re-aimed before each observation,
  data is to be stored electronically in the survey controller for archive).
- The Trimble S6 is to be removed and replaced with the Trimble S9 instrument.
- The Trimble S9 to be setup, manually aimed to the target and set to HA 0°00′30″
  (Continuing in the same Trimble job file created above).
- 20 observations will be made using AutoLock
- 20 observations will be made using FineLock

- 20 observations will be made using Manual sighting
  (Instrument is to be un-aimed and re-aimed before each observation,
  data is to be stored electronically in the survey controller for archive).
- The Trimble job file automatically captures all information about the observation including the Horizontal & Vertical angles, slope distance, prism constant, temperature settings, time of observations & observation technique. At the end of each day of observations this data is to be copied from the survey controller and archived for future processing.

Figure 3.2, Image of Trimble S6 Total Station

Figure 3.3, Image of Trimble S9 Total Station

3.4 Data Extraction

Each of the experimental conditions tested recorded 100 observations to the survey target that are to be extracted out of the Trimble Job File and displayed in a Microsoft Excel Spread Sheet for ease of data manipulation and analysis. To do this the Trimble Job File for each experimental condition was copied from the Trimble TS7 survey controller to a desktop computer with Trimble Business Centre (TBC) Installed.

Trimble Business Centre was launched, and a template job was created ensuring the TBC project settings were changed to display the largest number for decimals possible instead of rounding to the nearest second. This template was used each time a Trimble Job File was imported to allow us to fully view the data in the optics review listing.

The raw data was extracted from the optics review listing and imported into Microsoft Excel where listed under the appropriate headings. This data was then simplified by omitting the degrees and minutes as they remained constant throughout the experiments. The data listing for the observations were converted to only represent the seconds to simplify the statistical analysis.

3.5 Data Calculations

For each method of aiming the set of 20 observations for HA" and VA" per experiment where statistically analysed to the determine the range, average, the samples standard deviation of the mean (68% Confidence Level) and the 95% Confidence Level.

The Formula used to calculate these results are shown below:

Range = $\text{Largest Value} - \text{Smallest Value}$ Eq. (1)

Average = $\frac{\mathit{Sum\ of\ all\ Values}}{\mathit{Number\ of\ Observations}}$ Eq. (2)

Standard Deviation
(68% Confidence Level) = Eq. (3)

$$\sqrt{\frac{\mathit{Number\ of\ Observations}\ (\mathit{Value\ of\ Sample\ Observation} - \mathit{Average\ of\ Observations})^2}{\mathit{Number\ of\ Observations} - 1}}$$

95% Confidence Level = $\text{Sample Standard Deviation} \times 1.96$ Eq. (4)

As this information provides angular results in seconds that are difficult to determine the magnitude of, the HA" and VA" determined have been used to calculate the effect these angles create at the target distance in meters. These values are easier to interpret and assess as the magnitude is more visualizable.

The Formula used to calculate these results are shown below:

Effect of Angles at Target Range = $\tan\theta \times Target\ Range$ Eq. (5)

3.6 Result Analysis

The statistically calculated data was tabulated to allow for it to be analysed in terms of deviations of horizontal and vertical angles from the mean from each data set of 20 observations. The deviation of the results for both HA and VA are also represented at the 95% confidence level and in 'meters of effect of angular accuracy at target distance' for each of the five methods of aiming.

For further ease of interpreting this data, the effect in meters of the angular accuracy at the target distance with a 95% confidence level is shown visually in a series of bar graphs for each experimental condition.

The graphs with data from all five methods of aiming will then be analysed to confirm if any trends or anomalies can be identified in order to establish a solid justification for the results and determine which method of aiming affected the reliability of the survey results. The smaller the deviation from the mean angle the better accuracy is achieved for that method of aiming.

During statistical analysis it is not uncommon to come across outliers in the data being analysed. Sometimes these anomalies are identified and omitted or recaptured to correct a blunder. This research project is investigating the real-world results that a surveyor would obtain in the field, this should include any outliers to enable the true representation of accuracy. As such all observations have been included in the calculations, regardless if they may be an outlier or a blunder.

The use of two instruments with different prescribed measurement accuracies has been planned to discern if the fluctuation we observe in the data are in fact pointing error, not actual instrument angle measuring error. The comparison between ATR and manual sighting observations of each instrument shouldn't take into consideration the instrument angle measurement accuracy, as the angle measurement accuracy doesn't change with observation technique. The angle accuracy between instruments should only be noted when comparing observations between the instruments.

3.7 Project Planning

3.7.1 Resource Requirements

The successful completion of this project requires sufficient access to all of the required resources being analysed including surveying equipment and corresponding software. All of these resources have been made accessible and available from my employer for the duration of this research study.

A suitable testing location has also been explored, with access available to concrete survey pillars. A construction site at Springfield QLD has been identified as having the characteristics required to undertake this research. After comprehensive investigation and evaluation of the site, it was concluded that this site and its surroundings was in fact suitable for this research as it did have all the factors required to simulate each experimental condition to be tested.

All the equipment and software required to carry out the experiments are listed in the following table:

Table 3.1, Resource Availability

Item	Availability	Comment
Survey Vehicle	Yes	Safe access to testing site.
Survey Pillars	Yes	Two options, suitability to be assessed.
Trimble S6 Total Station	Yes	Currently used in students daily work.
Trimble S9 Total Station	Yes	Currently awaiting delivery of this instrument from the supplier, to be used in students daily work.
Survey Tripod	Yes	To be used for placement of targets only, Currently used in students daily work.
Survey Prism	Yes	Leica GPR111 model reflective traverse prism Currently used in students daily work.
Trimble TSC7	Yes	Used to store observations, currently awaiting delivery of this instrument from the supplier, to be used in students daily work.
Trimble Business Centre	Yes	Used to extract observations, Currently used in students daily work.
AutoCad	Yes	Analysis and creation of sketches. Currently used in students daily work.
Microsoft Word	Yes	Word processing of the thesis.
Microsoft Excel	Yes	Data analysis.
Laptop	Yes	For portable computing power.
Personal Protective Equipment	Yes	To ensure sun protection and other risk aversion measures.
Other Adhoc Items	As Required	These items may include sticky tape, zip ties, water, etc to be sourced if or when required.

3.7.2 Key Tasks and Project Schedule

Equally important as the equipment physically needed to undertake this study, the factor of time is also an imperative element required to complete the project. It is estimated that this research project may take between 400 to 500 hours of time to plan, test, record, analyse, and present the results in a professional format. This is a significant amount of time required to be invested into this research, considering the workloads of an external study student that works full time and has other personal commitments. To help schedule the flow of work and help allocate sufficient time to work on the project, a Gantt chart was prepared mapping the project schedule along a proposed timeline, as shown on the following page.

Table 3.2, Project Plan

Aleksandar Lazarevic Project Plan 2019																																				
Key Tasks	Semester 1																				Semester 2															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	(Week)
1. Project Preparation																																				
1.1 Final Approval from supervisor	■	■	■																																	
1.2 Litreture Review		■	■	■	■	■	■	■	■	■	■	■	■																							
1.3 Safety Analysis				■	■														■	■																
2. Experiment Stage																																				
2.1 Instrument Calibration					■										■	■																				
2.2 Collection of Data																	■	■	■																	
2.3 Initial Review of data																			■	■																
3. Analyses of Results																																				
3.1 Archive/Reduce data																					■	■	■													
3.2 Statistics																							■	■	■	■										
3.3 Modelling of Relative Tests																										■	■	■								
3.4 Analysis of Observations																							■	■	■	■	■	■	■							
4. Possible Extra Testing																																				
(Depending on Results)																												■	■	■						
5. Presentation / Report																																				
5.1 Draft Copy of Thesis						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■							
5.2 Preparation of PP2 Presentation																													■	■	■	■				
5.3 Finalize Thesis																															■	■	■	■		
5.4 Submit Thesis																																			■	
Fortnightly check-ins with supervisor: Method and time to be confirmed.																																				

3.7.3 Risk Assessment

An important part of every surveyors' daily tasks is to undertake a risk assessment for all field visits. A risk assessment and management document helps the surveyor to identify the possible risks they might encounter and the severity of damage that may be caused. Risk assessments also provide applicable counter measures that will help make the workplace safer. The need for risk management in the workplace is legislated in the *Work Health and Safety Act 2011.*

As this testing is proposed to be carried out on an unused section of a construction site to utilize the concrete survey control pillars, upon arrival the surveyors will have to sign in on the construction site entry register and work through the safe work method statement (SWMS) assessing the possible risks that may be encountered on that day. The SWMS that is tailored to the site is to be followed and incorporates risk assessment and control measures for a variety of surveying activities. This SWMS is incorporated on the following page for reference (Table 3.3).

Further to the possible risks encountered onsite other risks could be encountered in the office environment. Data loss due to computer problems is one of the largest risks to the project. To circumvent the risk of valuable data or files being corrupted or lots, copies of all working files are regularly backed up to several different locations including the office, offsite and cloud-based storage. Many hours will be spent at the computer researching and processing results, it is important that an ergonomic workstation is used, and regular study breaks are taken to avoid both physical and mental stresses on the human body.

Table 3.3, Safe Work Method Statement

SAFE WORK METHOD STATEMENT

LANDPARTNERS built environment consultants

LandPartners Pty Ltd
ABN: 19 118 146 008
Level 1, CDOP 6
18 Little Cribb Street
Milton QLD 4064
P: 07 3842 1000

Client:	Lendlease				
Project number:	WC007310.000				
Project name:	Springfield Rise Village 10 / Village 11				
Project address:	Grande Avenue, Spring Mountain				
Personnel:	Surveyor and Assistant	Prepared by:	Peter Barbaro – Project Director	Date:	12 JUL 18
				Review:	12 JUL 19

Scope of work:	Various survey activities within construction areas
Equipment used:	Total station, level, staff, GPS, UAV, sledgehammer, drill, 4WD vehicle and other small hand tools
Materials used:	Star pickets, timber stakes, flagging ribbon, spray paint, screws and nails
Requirements before works commence:	• General Construction Induction • Site specific induction as required • Vehicle Licence • Tertiary qualifications in Surveying • Work method to be tool boxed with all staff before they commence and during the activity including acknowledgement/sign off
Requirements during works:	• Vehicle to contain first aid kit, fire extinguisher and SDS information, flashing beacon when required • Regular review of controls to ensure they are adequate – Review SWMS by task observation • Obey safety and emergency response instructions from the Principal Contractor • Task rotation is to occur when carrying out prolonged and repetitive manual tasks such as swinging a brush hook or sledgehammer/kneeling/bending etc. if no assistant to rotate tasks with, take regular breaks.
References:	• Work Health and Safety Act 2011 (Qld) • Work Health and Safety Regulation 2011 (Qld) • AS2397 – Safe use of lasers in the building and construction industry

LANDPARTNERS CONTACTS	
Survey Manager	07 3842 1024 0403 049 992
Brisbane Office	07 3842 1000
Springfield Office	07 3470 8100
Sydney Office	02 9685 2000
Emergencies	000

PPE mandatory:
High visibility shirt, steel cap boots, helmet or wide brim hat if not on a construction site, safety glasses

PPE as required:
Gloves, hearing protection, reflective vests for rail/night work.

Assess project hazards using the matrix below, implement and monitor controls as appropriate. If residual risk is still high, reassess need & methodology.

RISK ASSESSMENT MATRIX		Consequence/Severity			
Likelihood/Frequency		Extreme: Death	Major: Serious injury	Moderate: Casualty	Minor: First aid
		Ext	Maj	Mod	Min
Very likely/Frequently	VL	1	2	3	4
Likely/Occasionally	L	2	3	4	5
Unlikely/Rare	UL	3	4	5	6
Very unlikely/Probably never	VUL	4	5	6	7

Risk ranking 1–2 = <u>High Risk.</u> Immediate action must be taken; work must not begin until hazard is appropriately controlled by eliminating the hazard or minimising the risk by following the hierarchy of controls.

Risk ranking 3–5 = <u>Medium Risk.</u> Risk management responsibility must be specified and appropriate controls implemented to eliminate the hazard or minimising risk by following the hierarchy of controls.

Risk ranking 6–7 = <u>Low Risk.</u> Manage by routine procedures to eliminate the hazard or minimising risk by following the hierarchy of controls.

TASK HEALTH AND SAFETY RISK ASSESSMENT

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No	Basic Job Step	Associated hazards	Control measures to be implemented	Residual risk	Who is responsible
1	Travelling to and from the worksite and within the worksite	Collision	Only nominated drivers are to drive vehicles. All signs and road rules to be strictly obeyed at all times, including site specific call-ups and speed limits. Reduce speed to walking pace when driving near pedestrians on construction sites. Obtain radio permission when overtaking and approaching plant on construction sites.	5	Nominated driver
		Hit by passing vehicle/ machinery	When leaving a vehicle unattended, ensure traffic can see vehicle and location is well away from corners. Ensure the vehicle is switched off in gear and the handbrake is on in full. Do not leave keys in an unattended vehicle and ensure doors are locked. Maintain communications with plant on site, make necessary call ups and give way to heavy vehicles. Use yellow flashing beacon when on construction sites.	5	Nominated driver
		Defective vehicle	Carry out safety checks and inspections on vehicle prior to departure to identify any faults or problems. Complete scheduled vehicle checks as outlined by the Survey Manager.	6	Nominated driver
		Being struck by unrestrained equipment	Ensure all loads are secure. Do not place loose items in the back seat or tray. Use approved netting/tie down straps to secure items. Speak to Survey Manager if your vehicle is deficient these items.	6	Driver & assistant
2	General Survey Work	Fatigue	Surveyors and Assistants are not to work more than 5 hours without a meal break. This break must be no less than 30 minutes or more than an hour per day. A paid rest break is allowed in the morning for 10 minutes. An afternoon tea break is also permitted. Under no circumstances is one member of a crew to force other member(s) to work through meal breaks against their will.	6	Surveyor, Assistant & Project Manager
		Hostile members of the public/land owners	Only enter private property if permission has been given by the client and/or landowner or tenant. This must be done through the client's liaison officer if required. If hostile member of the public or land owners are encountered then IMMEDIATELY leave the area and do not do anything to provoke them. After leaving the area notify your PM. Call police on '000' in an emergency situation.	6	Surveyor & assistant
		Injury from trips, slips, falls, strains or sprains	Plan your route carefully when walking through thick vegetation and uneven ground. Be extremely cautious of trip hazards. Do not carry large cumbersome loads, make multiple trips and carry smaller loads so vision and navigation isn't impeded. Avoid creating trip hazards for co-workers; use witches hats and barriers in areas of high foot traffic. Pay extra attention when walking on uneven terrain or uneven footpaths. Do not walk on concrete chamber lids, they may have decayed and collapse.	5	Surveyor & assistant
		Injuries associated with manual handling	Prior to lifting any item, assess the load and ensure it is not too heavy to lift. Ensure the path you intend to take is clear of trip hazards and that you're lifting posture will not require you to twist your body. If the load is too heavy attempt to break the load down into smaller parcels such as taking items out of the box or removing items from the bundle. Do not proceed with the lift if it is too heavy for your abilities. Use a team lift if available otherwise do not proceed. Do not carry heavy and cumbersome loads over uneven and rough terrain, break the load down and make multiple trips.	5	Surveyor & assistant

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No	Basic Job Step	Associated hazards	Control measures to be implemented	Residual risk	Who is responsible
			Refer to LandPartners SOPs for specific manual handling relating to use of sledgehammers, brush hooks and opening chamber lids.		
		Dehydration, heat stress, fatigue	Do not work in the field without adequate drinking water available in vehicle. If possible schedule office work for the hottest part of the day. A minimum of 10 hours rest between shifts is to be adhered to. Monitor colleagues for signs of heat stress. Take regular breaks in the shade.	5	Surveyor & assistant
		Exposure to Ultra Violet Light, glare, skin cancer, sunburn, eye damage	Wear a wide brimmed hat when working outdoors, if required to wear a helmet attach a helmet brim. Reapply sun cream every 2-3 hours. Wear safety sunglasses.	5	Surveyor & assistant
		Contact with overhead electrical services	**LOOK UP AND LIVE! - USE EXTREME CAUTION WHEN LEVELLING.** Ensure levelling staff does not come into contact with overhead power lines that may be present above sites and throughout suburban streets. Examine planned levelling route and identify areas where overhead power lines cross the route, constantly look up to maintain awareness of surroundings. A 3 metre exclusion zone around power lines MUST be observed. If levelling close to power lines the surveyor must act as a spotter while the mast carrier levels the mast. If the mast is going to be inside the exclusion zone then a new point must be used. It is easy to become distracted and forget how long the mast is, all parties must be extremely vigilant and always check the airspace above before moving the mast around. Be aware that electricity may arc across to a conducting material even if no direct contact is made with the power line.	4	Surveyor & assistant
		Exposure to hazardous substances (spray paint)	Adhere to manufacturer's instruction while using spray paint. Use in well-ventilated area aiming away from the body. Ensure SDS is located in vehicle folder.	7	Surveyor & assistant
		Falls from height	No access to any area is permitted where there is a significant risk of a fall from one level or another that is reasonably likely to cause injury to the person or any other person. These areas may only be accessed if fall protection is present in the form of edge protection of at least 900mm in height. This would consist of a physical barrier such as a wall, parapet or scaffold. If you need to access an area that is at height and there is no fall protection, then notify the principal contractor or project manager and have them arrange a safe method. Your feet **are not** to leave the ground or approved working platform to climb or access any structure no matter how quick you think you might be. Ladders may only be used for access and egress and are not to be used as work platforms.	4	Surveyor & assistant
		Strain injuries from pegging with a sledgehammer	Before use check sledgehammer to ensure that head is secure and handle is not splintered or cracked. Ensure you have stable footing and a safe posture when swinging a sledge hammer. Ensure there is no possibility of an over-swing striking yourself or someone near you. Wear leather gloves when handling stakes and wooden handled tools. Use appropriate amount of force for each task, over swinging can cause injuries. **Task rotation** is to occur with the assistant or another surveyor if	6	Surveyor & assistant

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LANDPARTNERS

No	Basic Job Step	Associated hazards	Control measures to be implemented	Residual risk	Who is responsible
			engaging in prolonged and repetitive sledgehammer use. Liaise with PM if working alone.		
		Injuries associated with using a brush hook	Before use check to ensure blade is properly secured to handle and that the handle is not splintered or cracked. Always swing brush hook away from body, do not over swing and keep a good grip on the handle. Blade must be sheathed when not in use. **Task rotation** is to occur with the assistant or another surveyor if engaging in prolonged and repetitive brush hook use. Liaise with PM if working alone.	6	Surveyor & assistant
		Exposure to asbestos	Asbestos only becomes dangerous when it is disturbed and its fibres can become inhaled. Asbestos Containing Materials (ACM) may be located in buildings built before 1990. Certain facilities may have asbestos registers that can be accessed prior to work. In construction environments, especially demolition sites, always check with the Principal Contractor about asbestos presence. Stop work, leave the area and notify the principal contractor/asset owner if you believe you have encountered asbestos. Refer to the LandPartners Safety Alert on asbestos.	6	Surveyor & assistant
		Noise	When working in areas where loud noises are present ensure hearing protection is worn. This includes if someone begins using loud tools or equipment close to you. Reschedule work if hearing protection will impede on your situational awareness and ability to respond to hazards.	6	Surveyor & assistant
3	Working on or near roads	Struck by vehicles	Follow the requirements outlined in **OHS.SOP.004 Working on or near roads,** this document states the minimum safe distances work can be performed during gaps in traffic with the aid of a spotter and the minimum safe distances equipment can be placed next to the road. Always ensure the use of a rotating beacon on vehicles. Use reflectorless theodolites to avoid work on roads. When leaving a vehicle unattended, ensure traffic can see vehicle and location is well away from corners. Advance warning signs **must** be placed for work on/next to roads as per the SOP.	4	Surveyor & assistant
4	Working near or above water	Drowning	Lifejackets must be worn if working on a boat or close to the edge of structures where there is a significant risk of falling into water. Do not approach the edge of fast flowing or flooding waterways. When asked to conduct a survey near a pond, dam, swamp or similar feature caution should be taken when approaching the area. The ground may be waterlogged and make access difficult. Gumboots and waders may be required if walking in this type of environment. Do not proceed further if it appears that you may become stuck or sink into mud.	5	Surveyor & assistant
5	Working in wildlife habitats	Bites, stings	Watch out for snakes when working in thick vegetation. Snake gaiters are available if you are performing prolonged work in thick vegetation or long grass. Ensure first aid kit contains adequate bandages. Be cautious of fire ants when disturbing soil, fire ants are coppery-brown coloured and range from 2-6mm in size.	5	Surveyor & assistant

No	Basic Job Step	Associated hazards	Control measures to be implemented	Residual risk	Who is responsible
			Report fire ant sightings to the site supervisor.		
6	Confined space entry	Contaminated atmosphere	No confined space entry is permitted on this project, this includes entering manholes.	4	Surveyor & assistant
7	Manhole inspection	Removing lid	When lifting lids use correct lifting technique, bend at knees not back. Rotate roles if need be. Assess position from where you are lifting from for slip/trip fall etc. Use Manhole Hook to assist with lifting manhole cap Ensure all feet/hands are out of the crush zone if cover were to fall.	6	Surveyor & assistant
		Public interference	Demark work area with safety cones – minimum of 3m exclusion zone from centre of manhole. All works/equipment/manhole covers are to be kept inside the work area which is defined by the safety cones.	6	Surveyor & assistant
		Falling in	Manhole Cover or suitable fall arrest to be placed over opening and to remain on at all times when not working directly in the opening. Ensure stable footing before attempting to measure manholes and overbalancing	6	Surveyor & assistant
		Exposure to hazardous gases/oxygen deficient atmosphere	Keep head a minimum of 300mm from manhole opening at all times. Crack Lid open slightly and allow manhole to breathe and release any built-up hazardous gases. **Do not place head inside opening or enter opening, no confined space entry is to occur.**	6	Surveyor & assistant
8	Working on or near trenches	Trench collapse	DO NOT enter trenches unless they are benched, battered or shored or less than 1m deep, notify client and trenching contractor of need to access and follow their directions. DO NOT place any equipment within 1.2m of the edge of an excavation, or within any barricades established around the excavation. Only use secured ladders or gentle slopes to gain access into a trench. DO NOT attempt to climb to the top of a cutting, batter or stockpile.	4	Surveyor & assistant
9	Surveying near powered mobile plant	Struck by moving plant	Inform site management and plant supervisor/operators of the survey activity. Discuss the safe location to set up equipment. High visibility clothing to be worn at all times. Obey all signs and call up instructions. Maintain radio comms with plant operators. If plant is in close proximity, ask principal contractor to provide a spotter, reschedule work if one is not available.	4	Surveyor & assistant
10	Working near scaffolding/elevated work platforms	Struck by falling objects	• Stay out of exclusion zones • Do not work in areas while work is carried out above • Work under protection decks • Use correct PPE and wear at all times. Always look up to remain aware of surroundings. Do not walk under suspended loads.	4	Surveyor & assistant

No	Basic Job Step	Associated hazards	Control measures to be implemented	Residual risk	Who is responsible
11	Working with survey equipment with laser components	Eye injury due to contact with laser radiation	All lasers are to be labelled with a classification number i.e. class 1, 2, 3R, etc. • No unclassified laser is to be used. • Lasers classes 1, 2 and 3R only are permitted to be used on construction sites. • Lasers are to be used and maintained in accordance with the manufacturer's instructions. • Lasers are to be calibrated and labelled in accordance with AS 2111 and manufacturer's specifications. • On site safety precautions appropriate to the class of laser are to be enforced. • DO NOT stare into the beam or view directly with optical instructions. • The stationary beam is to be terminated at the end of its useful path. • The beam is to be placed well above or below eye level. • Avoid directing laser beams at reflective surfaces or at any person. • The instrument is to be turned off when not in use. • All laser operators are to have appropriate training. • Laser warning signs are to be displayed in conspicuous locations. • Precautions are to be taken to prevent 'scattering' of the beam into other areas, e.g. by removal of ladders, containers, shiny surfaces and the like from the beam path.	5	Surveyor
12	Surveying in greenfields areas	Harm to flora and fauna	• Vehicles and pedestrians are to stick to existing tracks where possible and when required • Vehicles are to be parked and pedestrian access only is required in sensitive areas • All materials are to be removed from work areas and recycled appropriately • Use of spray marking paint is to be minimised in favour of non-chemical alternatives • Weed and seed wash-downs are to occur in agricultural areas and when otherwise required • Fauna sighting are to be reported to the fauna handler where appropriate • All Client/Project Environmental requirements are to be adhered to.	5	Project Manager & Surveyor

You are not required to work in any situation or with any equipment that you do not believe is safe. If you feel at risk you are to stop work, inform your supervisor of your concerns and sort the situation out.

DAILY CONSIDERATIONS – Use this area to add any additional hazards and controls that may arise after arriving at the project site

O:\Compliance\SWMS - Safe Work Method Statements\2017-2018 6

Supervisor's Signoff

I acknowledge that I am aware of and agree with the work methods described in this document. I agree to see that these work methods are implemented. I will communicate the work methods to each member of the work crew and respond immediately to any failure to comply. I will consult with the work crew and amend this Safe Work Method Statement as necessary in the event of any changes to the work method, equipment, sequence, materials or the like and in the event of any safety breaches, incidents or near misses.

Name of Project Supervisor:.........Peter Barbaro...

Signature of Project Supervisor:...Date...........12/07/2018............................

Work Crew Signoff

We have been consulted with in the formulation of this SWMS and understand the risks that are involved in carrying out this activity and are willing to implement the controls required to complete the work safely. We understand that a pre-site inspection is not practicable in every situation and must conduct our own risk assessment of the site and activity prior to commencing work and notifying the Survey Manager and Project Manager of unforeseen hazards.

Name	Signature	Date	Position
Aleks Lazarevic		12/07/2018	Project Surveyor
Jeremy Reynolds		12/07/2018	Project Surveyor
Ben Howell		12/07/2018	Project Surveyor
Russell Clancy		12/07/2018	Survey Assistant

3.7.4 Quality Assurance

The cataloguing of all data sets and experiments is crucial in ensuring the correct tests are being compared relatively to one another. With the expected large number of data files, it is proposed that an unambiguous and logical electronic folder structure be created and implemented to trace and organise the data. Each dataset will have notes as to the work performed, and the dissertation will be checked regularly to ensure there are no blunders or errors by miss identification between datasets.

Each experimental condition was numbered 1 through to 10 and received its own electronic data folder labelled by experiment number. All of the data for the individual experiments was stored in the appropriate subject folder along with a noting file containing the associated meta data. To further aid in the clarity each method of aiming had an allocated point number range for raw data. As 100 observations were taken per experiment a three-digit point number was chosen. The first number indicated the experiment number and the following 2 digits were the number of the observation.
The observation rangers were:

- S6 AutoLock 00-19
- S6 Manual Aiming 20-39
- S9 AutoLock 40-59
- S9 FineLock 60-79
- S9 Manual 80-99

As a result of this numbering procedure the point number 565 could easily be identified as an experiment 5 S9 FineLock observation. The method of observation was also stored as the point code to verify between the two identification systems.

3.8 Summary

The testing location chosen allowed for a wide variety of experimental conditions to be tested all while utilizing the stable concrete survey pillars. Observations were systematically taken as outlined in this chapter and archived appropriately for each of the 10 different experimental conditions. The data was checked to ensure it is fit for purpose then was statistically analysed and investigated as intended, the analysed data will be presented and in future chapters.

4. Results

4.1 Introduction

This chapter contains all the information captured during for each experiment during the field-testing phase and statistical analyse phase. The experimental conditions recorded include, target range, air temperature, wind strength, level of daylight/darkness and any obstructions identified or simulated.

The results and statistical calculations from each experiment have been tabulated in sub-section 4.3, further to this the all raw total station observations have been included in Appendix B.

For further ease of interpreting the effect of angular accuracy at the target range has been shown visually in a series of bar graphs for each experimental test condition at a 95% confidence level. These graphs can be seen in section 4.4.

4.2 Experimental Conditions

<u>Experiment 1:</u>

- Target distance of 471.680m.
- At very limit of manual sighting range.
- Clear line of sight.
- Line of sight a large distance off ground (>20m).
- Heat shimmer not visible by eye.
- Heat shimmer through eye piece (almost unreadable) shimmer improves when gusts of wind come through making it easier to read manually.
- Sunny 24°C slight breeze.

Figure 4.1, Experiment 1 – Outlook from Observation Pillar to Reflective Prism

Experiment 2:

- Target distance of 153.821m.
- Steep observation down face of large hill (bark covered landscaped area).
- Clear line of sight.
- Line of sight approximately 1.5-2m off ground the entire length of observation.
- Heat shimmer not obvious by visible by eye.
- Heat shimmer very visible through eye piece.
- Sunny 24°C slight breeze.

Figure 4.2, Experiment 2 – Outlook from Observation Pillar to Target Located at Cull-dee-sac

Experiment 3:

- Target distance of 54.667m.
- Scattered vegetation along line of sight (leaves and branches from tree regrowth).
- No heat shimmer visible by eye or through eyepiece.
- Vegetation obvious through eye piece (bouncing leaves).
- FineLock mode was unable to take a measurement through the interrupted signal.
- Clear sky 22°C slight breeze.

Figure 4.3, Experiment 3 – Outlook from Observation Pillar to Target Located in Bushland

Experiment 4:

- Target distance of 39.142m.
- Line of sight across the top of a small patch section of tall thin grass.
- (Patch no greater than 2m diameter located approximately midway along line of sight)
- Dusk 22°C slight breeze.

Figure 4.4, Experiment 4 – Magnitude of the Grass Obstruction Tested

Experiment 5:

- Target distance of 153.821m.
- The exact target setup as experiment 2 however the observations were taken at night.
- Steep observation down face of large hill (landscaped bark covered area).
- Clear line of sight.
- Line of sight approximately 1.5-2m off ground the entire length of observation.
- No heat shimmer visible by eye or through eye piece.
- Poor visibility of target due to low light, a flashlight was used to help sight the target.
- Dark 19°C slight breeze.

Figure 4.5, Experiment 5 – Flashlight Setup Used to Aid Low Light Observations.

Experiment 6:

- Target distance of 294.292m.
- Clear line of sight.
- No excessive amounts of heat shimmer (normal survey conditions).
- Sun shining into eye piece.
- Sunset 22°C.

Figure 4.6, Experiment 6 – Sunlight Shinning Directly into Instrument

Experiment 7:

- Target distance of 294.292m.
- The exact target setup as experiment 6 however the observations were taken at night.
- Clear line of sight.
- No heat shimmer visible by eye or through eye piece.
- Poor visibility of target due to low light, a flashlight was used to help sight the target.
- Dusk/dark 20°C.

Figure 4.7, Experiment 7 – Flashlight Setup Being Used to Aid in Low Light Observations

Experiment 8:

- Target distance of 166.592m.
- Simulated rain from garden hose with spray attachment.
  (Realistic water droplets similar to those when surveying might occur)
- Clear line of sight (only impacted by water droplets).
- No heat shimmer noticeable by eye or through eye piece.
- Sunny 25°C strong wind.

Figure 4.8, Experiment 8 – Garden Hose Spray Attachment

Experiment 9:

- Target distance of 100.172m.
- Reflective street sign in close proximity but clear of line of sight.
- No heat shimmer visible by eye.
- No excessive amounts of heat shimmer (normal survey conditions).
- Sunny 25°C strong wind.

Figure 4.9, Experiment 9 – Reflective Sign Along Survey Line

Experiment 10:

- Target distance of 155.110m.
- Construction temporary fencing on line of sight.
- No visible obstructions by eye as target or temporary fencing is some distance away.
- Temporary fencing visible through eye piece.
- No heat shimmer visible by eye.
- Some heat shimmer visible through eye piece.
- Temporary construction fence makes it harder to manually aim the instrument.
- Sunny 25°C strong wind.

Figure 4.10, Experiment 10 – Temporary Construction Fencing

4.3 Observations and Statistical Data

A Sample of the raw data as extracted from the Trimble Business Station software be seen below.

EXPERIMENT 1

From Point ID	To Point ID	H. Angle	V. Angle	H. Distance
1	100	0°00'30.831840000"	Z89°20'33.964282069"	471.64798
1	101	0°00'32.419440000"	Z89°20'32.972888544"	471.64695
1	102	0°00'31.936680000"	Z89°20'32.490150997"	471.64721
1	103	0°00'33.067440000"	Z89°20'33.786090439"	471.64772

The full catalogue of the raw data can be found in Appendix B. The following series of tables for each experiment (tables 4.1 to 4.10) contain: listings of both HA and VA observations displayed as seconds of arc; the results of the statistical calculations in seconds of arc; along with the results of the statistical calculations converted to the magnitude of effect these figures would have at the range of the reflective target in meters.

The statistics section of the follow tables have been populated using the following equations.

Range:	Eq. (1)
Average:	Eq. (2)
Standard Deviation of Mean 68% CL:	Eq. (3)
Accuracy at 95% Confidence Level:	Eq. (4)
Effect of Angular Accuracy at Target Range (m)	Eq. (5)

Table 4.1, Observations and Statistical Calculations – Experiment 1

Experiment 1 Observations	S6 AutoLock		S6 Manual		S9 AutoLock		S9 FineLock		S9 Manual	
	HA"	VA"	HA"	VA"	HA"	VA"	HA"	VA"	HA"	VA"
	30.83184	33.96428207	30.44952	35.68464148	29.4354	26.87873232	31.47336	26.24048216	29.6136	29.47709099
	32.41944	32.97288854	30.32964	34.08091651	48.4704	50.1926859	31.41504	27.44894583	28.53144	29.55484755
	31.93668	32.490151	30.28752	35.35741708	31.74876	28.88743864	31.77792	27.51698249	28.76472	29.66824227
	33.06744	33.78609044	31.56084	37.44711937	31.43772	28.7805237	32.00472	25.84198072	30.84804	27.73729226
	55.161	38.60050567	28.81008	38.51302985	30.56616	26.71026027	31.79736	26.17244529	28.84248	30.75035192
	32.90868	33.89300579	29.6298	34.08091681	32.39352	27.8053292	30.46248	27.06664364	31.38912	26.58066637
	35.35164	38.99576771	30.49488	35.02695241	33.88068	25.26528767	32.24124	27.78265018	30.38472	31.52143576
	30.67632	32.59382648	31.92696	33.91892397	34.10748	23.13346718	31.671	26.09792891	30.8124	26.23724228
	31.80708	34.79692345	32.1732	31.41776082	31.13316	24.96722165	31.50252	27.94464273	29.22804	28.70276723
	33.18732	33.16403965	34.35048	33.90920467	35.03412	24.02442566	32.58792	27.33231125	30.88692	26.77181744
	31.33728	33.6629764	31.6386	37.77434432	32.47128	26.18864457	31.32756	26.09792876	30.34584	29.62936418
	30.72492	33.30011335	32.66568	36.99678062	32.00472	26.67138213	31.023	25.51151615	31.1202	26.07848966
	31.8654	34.50209729	31.84596	33.26123545	31.35024	24.47476466	31.70988	25.41108089	31.15908	28.81940177
	32.66244	34.3433444	34.5546	35.15006687	30.95496	26.5644672	31.5738	25.58927244	29.73024	29.86263331
	31.33404	34.10683548	34.26948	33.26123503	33.34608	24.87974552	31.45392	26.1206077	30.34584	27.08284289
	32.11488	32.88541266	33.777	32.8108961	30.59208	28.08071644	30.44304	27.72757278	30.8124	26.61954445
	35.13456	31.48579754	31.38264	35.47729129	32.0598	26.11736776	32.65596	28.12283446	28.72584	24.2220563
	34.77168	33.64677685	34.26948	36.87366638	31.19148	26.54502793	30.79296	26.9305699	30.69576	28.39498154
	35.74692	36.18681868	33.4854	31.74498563	33.07392	24.97046142	31.93668	28.11311483	31.27572	29.9015112
	30.67632	32.59382648	32.99292	33.18023868	30.98088	23.44125267	32.04684	27.04720453	32.74344	28.97491459
Angular Accuracy Statistics (0.000")										
RANGE	24.48468	7.509970171	5.74452	7.095269028	19.035	27.05921872	2.21292	2.711753569	4.212	7.299379459
AVERAGE	33.685794	34.098574	32.044734	34.79838117	32.811642	27.22896012	31.59486	26.80583578	30.312792	28.3293747
σ (68% CL)	5.300516406	1.892713825	1.717619596	1.98924616	3.930859952	5.647745814	0.599955566	0.920660612	1.097512122	1.843915794
(95% CL)	10.38901216	3.709719097	3.366534409	3.898922473	7.704485506	11.06958179	1.17591291	1.804494799	2.151123759	3.614074956
Effect of Angular Accuracy at Target Distance (m)										
RANGE	0.0560	0.0172	0.0131	0.0162	0.0435	0.0619	0.0051	0.0062	0.0096	0.0167
σ (68% CL)	0.0121	0.0043	0.0039	0.0045	0.0090	0.0129	0.0014	0.0021	0.0025	0.0042
(95% CL)	**0.0238**	**0.0085**	**0.0077**	**0.0089**	**0.0176**	**0.0253**	**0.0027**	**0.0041**	**0.0049**	**0.0083**
Target Distance	471.680									

Table 4.2, Observations and Statistical Calculations – Experiment 2

Experiment 2 Observations	S6 AutoLock		S6 Manual		S9 AutoLock		S9 FineLock		S9 Manual	
	HA"	VA"	HA"	VA"	HA"	VA"	HA"	VA"	HA"	VA"
	30.90636	36.25404	26.96328	29.40792	32.44536	27.9564	31.45716	33.80784	28.64484	26.72844
	30.97116	40.08372	30.36528	27.68424	31.98852	24.5382	31.6386	26.4012	27.4104	26.07072
	32.7402	37.94856	30.44952	26.19384	33.64416	28.49424	31.62564	26.5794	24.2028	25.95732
	29.96028	35.133	29.7108	28.20588	31.85244	28.248	33.17112	26.02212	27.06372	28.89276
	33.35904	33.91152	29.17944	28.87332	32.86656	32.95248	31.21092	31.29684	28.64484	24.56412
	30.67632	39.13116	29.2086	32.52804	30.35556	31.66296	34.71984	21.3306	28.95588	19.62312
	31.12344	35.07468	29.87928	32.19756	30.56616	35.98512	30.02832	25.19268	28.45368	19.08204
	33.95844	35.67408	28.5606	31.49772	26.25696	32.61552	31.84596	21.69672	29.9214	26.22624
	33.13224	35.02932	30.3264	26.37204	35.6886	27.48336	33.29424	26.02212	28.49256	26.84508
	25.9038	35.67408	29.95704	29.3658	36.7902	31.23852	33.3882	24.2142	27.52704	26.34288
	31.96908	28.70808	30.98412	29.16168	29.61036	35.75832	33.8742	22.12764	28.80036	24.87516
	34.15284	28.81824	26.4708	31.28064	31.98204	31.85736	33.80616	23.61804	30.34584	25.18296
	22.36572	42.81504	31.3956	33.87912	27.9936	34.52064	35.74368	23.19036	27.4104	30.66828
	27.7506	42.93168	28.72584	29.20056	33.10308	30.62616	31.11372	25.11492	27.95148	24.70668
	32.25744	34.971	33.32016	31.64676	27.70524	31.083	32.4324	27.9888	27.44928	23.0964
	30.17736	31.92216	29.99916	33.02052	28.29492	23.72496	31.10724	29.33664	25.28496	28.39056
	28.07784	36.03372	32.66568	31.69212	34.77168	27.97908	30.2778	28.78908	26.94708	23.75412
	33.82884	30.86592	31.4766	35.25936	27.44928	31.488	29.42244	32.95248	28.917	19.52916
	30.02832	37.52412	30.65688	34.25172	34.6194	34.9548	32.72724	29.13252	29.53584	23.75412
	31.2012	33.07236	29.62656	37.12236	31.59972	28.98348	30.21948	25.65276	28.917	24.603
Angular Accuracy Statistics (0.000")										
RANGE	11.78712	14.2236	6.84936	10.92852	10.53324	12.26016	6.32124	12.47724	6.14304	11.58624
AVERAGE	30.727026	35.578824	29.996082	30.94206	31.479192	30.60753	32.155218	26.523348	28.04382	24.944658
σ (68% CL)	2.932185826	3.894011436	1.638524589	2.930427875	2.929954618	3.432369473	1.667918078	3.544343656	1.469538198	3.004849964
(95% CL)	5.747084218	7.632262414	3.211508195	5.743638635	5.742711052	6.727444167	3.269119433	6.946913565	2.880294867	5.889505929
Effect of Angular Accuracy at Target Distance (m)										
RANGE	0.0088	0.0106	0.0051	0.0081	0.0079	0.0091	0.0047	0.0093	0.0046	0.0086
σ (68% CL)	0.0022	0.0029	0.0012	0.0022	0.0022	0.0026	0.0012	0.0026	0.0011	0.0022
(95% CL)	**0.0043**	**0.0057**	**0.0024**	**0.0043**	**0.0043**	**0.0050**	**0.0024**	**0.0052**	**0.0021**	**0.0044**
Target Distance	153.821									

Table 4.3, Observations and Statistical Calculations – Experiment 3

Experiment 3 Observations	S6 AutoLock		S6 Manual		S9 AutoLock		S9 FineLock		S9 Manual	
	HA"	VA"	HA"	VA"	HA"	VA"	HA"	VA"	HA"	VA"
	33.54696	46.45476	29.42892	50.88708	84.31452	43.14672	0	0	26.83368	42.34644
	23.6196	41.90904	32.1732	47.64708	28.70964	30.87036	0	0	25.71264	38.98332
	35.19612	46.12104	35.57844	46.65564	24.63048	48.87828	0	0	27.41364	38.52
	46.36764	61.35876	30.82212	49.65588	32.91516	49.74984	0	0	25.596	39.87432
	121.88232	27.52668	31.46364	43.33464	26.40276	49.04028	0	0	26.487	43.88868
	24.53328	47.66976	27.54	46.49364	4.38372	41.04072	0	0	26.0982	41.49432
	34.82028	39.05136	29.21832	45.87804	25.22988	43.59384	0	0	26.02044	42.5376
	20.86884	26.80416	37.18224	46.9602	35.10864	51.50268	0	0	25.17156	47.28744
	36.52128	35.50356	30.24864	45.05832	39.84552	44.46864	0	0	28.53144	39.29436
	30.91284	46.83384	32.79204	46.28952	19.76076	47.57256	0	0	29.18916	41.7276
	36.01908	40.78152	34.4736	49.03704	39.609	43.98588	0	0	26.83368	45.8586
	29.05632	46.07568	29.5488	48.79404	25.63488	50.72508	0	0	29.57472	42.07428
	26.62632	43.47072	28.3176	48.21732	28.97532	40.21128	0	0	31.54464	42.61536
	10.56888	42.732	32.87304	43.37352	6.68088	44.30016	0	0	25.75152	44.00532
	20.56428	82.97604	31.35348	49.19904	28.07784	46.68156	0	0	27.25812	46.39968
	47.18088	50.92272	28.08108	50.34924	30.132	42.60888	0	0	31.04244	41.57208
	79.74936	-19.3464	29.95704	49.3254	29.15028	42.17148	0	0	23.82048	40.29876
	-2.349	43.43184	30.0024	48.46356	29.53584	45.03564	0	0	25.4826	38.98332
	13.90608	16.02144	29.13732	51.8526	-17.63208	40.31172	0	0	27.95472	40.64544
	26.46432	40.39596	29.83716	45.1782	31.43448	44.75376	0	0	28.76472	40.99212
Angular Accuracy Statistics (0.000")										
RANGE	124.23132	102.32244	9.64224	8.51796	101.9466	20.63232	0	0	7.72416	8.76744
AVERAGE	34.802784	40.334724	31.001454	47.6325	27.644976	44.532468	0	0	27.25407	41.969952
σ (68% CL)	26.27018694	19.36528466	2.540416489	2.366393033	18.81998181	4.675175659	0	0	2.010079056	2.502363138
(95% CL)	51.48956641	37.95595794	4.979216318	4.638130345	36.88716434	9.163344292	0	0	3.93975495	4.90463175
Effect of Angular Accuracy at Target Distance (m)										
RANGE	0.0329	0.0271	0.0026	0.0023	0.0270	0.0055	0.0000	0.0000	0.0020	0.0023
σ (68% CL)	0.0070	0.0051	0.0007	0.0006	0.0050	0.0012	0.0000	0.0000	0.0005	0.0007
(95% CL)	**0.0136**	**0.0101**	**0.0013**	**0.0012**	**0.0098**	**0.0024**	**0.0000**	**0.0000**	**0.0010**	**0.0013**
Target Distance	54.667									

Table 4.4, Observations and Statistical Calculations – Experiment 4

Experiment 4 Observations	S6 AutoLock		S6 Manual		S9 AutoLock		S9 FineLock		S9 Manual	
	HA"	VA"	HA"	VA"	HA"	VA"	HA"	VA"	HA"	VA"
	24.01812	50.08152	25.68672	53.12064	27.69552	50.74572	25.272	46.79292	25.32384	51.16044
	24.99336	48.16992	26.23428	55.00956	28.93968	49.51452	23.98896	48.39672	25.9038	50.81376
	21.02436	49.9584	20.88828	54.06996	25.91352	50.35044	29.16648	52.0806	27.6048	48.57492
	28.14912	46.89336	21.74364	54.68232	22.87764	53.814	31.50576	48.2736	26.67816	52.32036
	12.82392	51.384	27.20952	49.20996	24.48144	50.66796	36.10008	48.468	28.02924	50.1204
	21.0924	50.9304	29.50668	55.00956	22.94568	50.76192	28.27872	50.43144	27.06372	50.35044
	20.25	45.0012	28.5606	51.8538	19.43352	51.69828	27.57888	43.15764	30.57912	50.19492
	27.61452	51.8376	26.6328	55.13592	29.65572	47.76168	23.32152	50.45736	29.38032	50.4282
	26.97624	49.83528	20.76192	54.88968	31.63536	46.8804	26.01072	49.75752	28.53144	50.19492
	23.21136	50.78136	29.26044	54.3972	33.4206	49.08684	34.04916	50.99844	32.54904	53.32476
	24.69204	53.03964	24.948	57.73764	28.29492	50.35044	28.93968	46.93872	29.34144	51.19932
	23.20164	52.19076	23.26968	51.9348	31.65804	50.17224	29.2734	49.64736	31.11696	48.99936
	33.90984	50.92392	26.99892	49.2456	38.06028	47.54136	30.1158	48.61704	28.107	44.01624
	30.66984	56.25048	22.52124	49.0188	19.04796	52.31064	27.22248	50.4768	30.19032	48.57492
	27.3294	45.12756	25.93296	53.45112	35.73396	45.70752	33.08364	50.8332	26.28936	47.1072
	13.80564	61.22712	24.74712	51.141	29.19564	50.95308	31.64508	45.86628	29.53584	48.7272
	21.45852	53.86908	25.34004	51.76956	24.1218	51.12804	33.49512	51.86352	26.6004	48.30276
	22.96512	50.16252	21.13452	50.331	28.8684	47.9982	21.89592	43.95468	27.9126	46.75728
	26.9892	52.13244	24.97716	52.18104	19.62468	50.52864	19.82556	47.8686	31.04244	53.86584
	14.6124	61.60944	25.4016	55.7094	24.70824	46.71192	29.3382	49.3752	24.35832	49.19052
Angular Accuracy Statistics (0.000")										
RANGE	21.08592	16.60824	8.74476	8.71884	19.01232	8.10648	16.27452	8.92296	8.19072	9.8496
AVERAGE	23.489352	51.5703	25.087806	52.994928	27.31563	49.734192	28.505358	48.712782	28.306908	49.711188
σ (68% CL)	5.40573735	4.313674249	2.668431939	2.42425183	5.289950676	2.061879589	4.24984131	2.428037353	2.153088735	2.276495568
(95% CL)	10.59524521	8.454801529	5.230126601	4.751533588	10.36830332	4.041283995	8.329688968	4.758953212	4.220053921	4.461931314
Effect of Angular Accuracy at Target Distance (m)										
RANGE	0.0040	0.0032	0.0017	0.0017	0.0036	0.0015	0.0031	0.0017	0.0016	0.0019
σ (68% CL)	0.0010	0.0008	0.0005	0.0005	0.0010	0.0004	0.0008	0.0005	0.0004	0.0004
(95% CL)	**0.0020**	**0.0016**	**0.0010**	**0.0009**	**0.0020**	**0.0008**	**0.0016**	**0.0009**	**0.0008**	**0.0008**
Target Distance	39.142									

Table 4.5, Observations and Statistical Calculations – Experiment 5

Experiment 5 Observations	S6 AutoLock		S6 Manual		S9 AutoLock		S9 FineLock		S9 Manual	
	HA"	VA"	HA"	VA"	HA"	VA"	HA"	VA"	HA"	VA"
	30.72168	23.02188	29.6298	15.86472	35.56872	18.80988	34.91424	18.16512	29.80476	10.73904
	27.85428	23.21304	27.30024	14.42616	35.92836	19.6782	35.06328	16.73952	30.03804	15.87444
	37.50624	27.54816	28.6416	14.5104	36.21672	18.42108	34.30512	17.83464	28.53144	18.54096
	32.09868	23.67636	29.42244	16.2762	35.03088	18.97836	35.03412	16.98252	30.69252	15.37224
	29.88576	23.35884	28.48284	14.79876	35.2998	18.3336	35.03412	16.49004	31.31136	15.72216
	33.27156	23.70552	27.99036	14.01792	34.95312	17.54952	35.47476	18.63816	30.26808	17.49768
	30.85128	22.92792	30.65364	16.64232	46.30608	20.21604	35.78256	17.35836	29.4192	18.22992
	32.81796	24.38592	30.81888	16.80756	36.41436	17.29032	34.93692	18.63168	33.05124	19.2732
	31.58676	23.5662	28.3176	18.57336	34.85592	18.55392	34.09776	19.53564	31.96908	19.54536
	30.22596	23.4366	27.45252	16.14984	35.84088	16.93392	34.4736	19.46112	34.32456	18.771
	30.58236	23.65368	30.20652	19.6782	34.75548	18.57984	34.63884	20.25816	31.7358	16.49328
	30.5856	23.76384	30.20652	19.6782	36.20376	16.67148	35.2998	19.66524	29.15028	16.49328
	44.1288	17.51064	29.1762	16.56132	34.63236	15.91008	35.16372	18.90708	29.15028	16.49328
	28.836	23.80272	29.38356	18.93948	34.39584	17.68236	34.14636	19.08528	29.6136	17.61432
	29.8728	24.31464	27.29052	17.54628	35.97048	18.11976	34.6032	18.71268	29.6136	17.61432
	29.36412	24.12996	27.29052	17.54628	34.8786	18.43404	34.749	18.55392	32.04684	18.80988
	30.2778	23.65692	27.29052	17.1348	34.29216	17.7828	35.0406	18.29472	29.18592	17.151
	30.5856	24.41508	28.81008	18.85848	35.23824	18.36276	35.18964	19.27968	29.68812	16.99548
	26.89848	25.96704	29.96028	20.62752	38.67588	16.51596	34.4736	18.80016	29.6136	19.12092
	29.94084	23.80272	28.07136	17.62728	35.83116	16.0818	34.69068	18.22668	29.6136	19.12092
Angular Accuracy Statistics (0.000")										
RANGE	17.23032	10.03752	3.52836	6.6096	12.01392	4.30596	1.6848	3.76812	5.79312	8.80632
AVERAGE	31.394628	23.692884	28.8198	17.113254	36.06444	17.945286	34.855596	18.48102	30.441096	17.273634
σ (68% CL)	3.706661077	1.796575241	1.187886879	1.883464281	2.599393282	1.136757845	0.436436919	1.003830776	1.500988181	1.999859453
(95% CL)	7.265055711	3.521287472	2.328258282	3.69158999	5.094810833	2.228045377	0.855416361	1.967508321	2.941936834	3.919724528
Effect of Angular Accuracy at Target Distance (m)										
RANGE	0.0128	0.0075	0.0026	0.0049	0.0090	0.0032	0.0013	0.0028	0.0043	0.0066
σ (68% CL)	0.0028	0.0013	0.0009	0.0014	0.0019	0.0008	0.0003	0.0007	0.0011	0.0015
(95% CL)	**0.0054**	**0.0026**	**0.0017**	**0.0028**	**0.0038**	**0.0017**	**0.0006**	**0.0015**	**0.0022**	**0.0029**
Target Distance	153.821									

Table 4.6, Observations and Statistical Calculations – Experiment 6

Experiment 6 Observations	S6 AutoLock		S6 Manual		S9 AutoLock		S9 FineLock		S9 Manual	
	HA"	VA"	HA"	VA"	HA"	VA"	HA"	VA"	HA"	VA"
	30.57912	6.90396	29.42244	7.67184	34.7166	8.54016	34.78464	4.6392	30.26808	1.14
	30.89016	6.08424	30.78	7.41588	37.179	7.01088	34.78464	4.8822	28.29816	1.71996
	30.79944	7.11132	31.31136	7.57464	34.62264	7.86948	33.97788	6.83592	30.54024	0.90672
	34.3926	9.61584	29.96028	6.91692	34.88832	6.46332	34.66152	5.4654	30.4236	0.05784
	26.61984	7.1016	29.30256	7.04976	33.9714	6.93636	34.59996	6.23652	31.35024	1.7556
	30.26808	8.14812	31.76496	7.701	34.88832	6.8262	34.7976	5.77968	30.38472	0.79008
	24.0246	11.30064	28.40832	6.79704	34.32456	6.34344	34.23708	6.324	30.54024	-0.01992
	22.21668	10.72392	28.19124	6.79704	34.8462	6.1944	34.73928	6.28512	30.7314	1.37004
	30.49488	6.69012	28.76796	6.79704	34.21764	7.25064	34.5384	5.29692	29.80476	-2.53092
	24.42312	9.67092	29.26044	8.6406	35.2674	5.42004	34.81704	5.676	31.6224	0.67668
	-8.181	13.11828	30.09636	6.58968	37.017	5.271	34.88832	5.26776	30.38472	0.52116
	32.10192	9.16224	31.02624	7.90188	34.992	7.1502	34.56432	4.85628	30.54024	-0.79104
	31.30812	7.93752	30.57264	8.10924	34.93692	6.98496	34.15608	5.03124	31.1202	-0.94656
	38.3454	14.02872	31.14612	7.00116	34.83	6.9072	34.59348	6.324	29.30256	-1.33212
	30.46572	7.85328	31.14612	7.00116	35.51364	7.38672	33.15168	5.5626	29.57472	-1.40988
	41.09616	6.48924	31.84596	7.12428	35.64648	7.39968	33.63444	4.64568	30.7314	-0.82992
	31.14612	7.59732	31.27248	8.35548	34.50276	9.40524	33.7446	4.61652	30.15468	-1.83432
	30.99384	8.01528	31.23036	6.243	34.42176	5.62416	33.63768	3.77088	30.4236	-1.68204
	31.11372	7.0206	29.38356	6.30456	35.1702	7.44828	31.95936	4.3152	31.7358	-3.30204
	31.1364	6.73872	30.25836	7.28952	28.23984	6.57024	33.696	2.46516	29.68812	-0.98544
Angular Accuracy Statistics (0.000")										
RANGE	49.27716	7.94448	3.65472	2.3976	8.93916	4.13424	2.92896	4.37076	3.43764	5.05764
AVERAGE	28.711746	8.565594	30.257388	7.264086	34.709634	6.95013	34.1982	5.213814	30.380994	-0.336306
σ (68% CL)	9.702787481	2.229447712	1.119552132	0.652165593	1.726332744	0.984987416	0.733793462	1.019390319	0.801811735	1.443341873
(95% CL)	19.01746346	4.369717516	2.194322178	1.278244562	3.383612178	1.930575335	1.438235185	1.998005026	1.571551	2.828950072
Effect of Angular Accuracy at Target Distance (m)										
RANGE	0.0703	0.0113	0.0052	0.0034	0.0128	0.0059	0.0042	0.0062	0.0049	0.0072
σ (68% CL)	0.0138	0.0032	0.0016	0.0009	0.0025	0.0014	0.0010	0.0015	0.0011	0.0021
(95% CL)	**0.0271**	**0.0062**	**0.0031**	**0.0018**	**0.0048**	**0.0028**	**0.0021**	**0.0029**	**0.0022**	**0.0040**
Target Distance	294.292									

Table 4.7, Observations and Statistical Calculations – Experiment 7

	Experiment 7 Observations									
	S6 AutoLock		S6 Manual		S9 AutoLock		S9 FineLock		S9 Manual	
	HA"	VA"	HA"	VA"	HA"	VA"	HA"	VA"	HA"	VA"
	29.99592	3.47604	31.14936	0.79008	33.0642	-1.03404	32.75316	-0.28884	28.88136	-3.072
	29.60712	3.51492	30.53376	1.221	33.66684	-2.39484	32.9508	-0.17868	28.45692	-2.21988
	29.69136	2.76	29.83392	-0.4962	32.9994	-0.22728	32.9508	-0.57072	28.998	-1.98984
	29.44512	3.084	27.33264	-0.0588	33.34932	-0.39252	32.86008	-0.48648	28.84248	-3.80424
	18.1116	2.70816	30.2454	0.98124	33.32988	-1.047	32.89248	-0.6096	28.6902	-3.61308
	32.14404	2.02128	29.62656	2.56884	37.57104	2.06988	32.64948	-0.2694	28.72908	-3.64872
	29.16324	2.54292	31.3956	1.90788	33.06744	-0.0102	32.967	-0.6582	27.64692	-2.99424
	29.40948	3.69636	30.81888	-2.1486	32.85684	-0.07824	32.92812	-0.40548	27.76356	-3.92088
	36.17784	-1.13448	30.53376	1.87224	32.70132	-0.62256	32.47452	-0.6582	28.65132	-3.34092
	31.40532	1.54824	29.75292	1.13028	33.13872	-0.33744	32.7888	-0.4638	29.23128	-2.72208
	30.53376	1.70376	29.63304	2.36472	37.22112	-0.68088	32.76288	-0.67116	27.6858	-3.99864
	29.91168	2.10876	29.63304	2.36472	32.79852	0.01572	32.76936	-0.51564	28.37916	-3.61308
	29.88252	1.63572	30.49164	1.74588	32.38704	0.4596	32.49396	-0.45084	29.3058	-3.95976
	30.06072	1.94028	29.04336	0.47904	32.93784	-0.32448	32.724	-0.885	28.188	-4.1898
	31.752	2.83776	31.35672	-2.1486	33.21648	-0.29532	32.61384	-1.40664	27.72468	-3.1854
	29.76912	2.73084	30.94524	2.4036	32.80176	-0.3828	32.87952	-1.05672	28.61244	-3.3798
	32.45184	1.8042	30.98412	1.49964	32.83092	0.48876	32.80176	-0.74244	28.61244	-3.3798
	26.44164	0.50496	30.98412	1.49964	32.06952	4.09488	32.6916	-1.01784	27.22248	-2.5698
	34.0848	1.74588	30.86424	0.2328	32.57496	0.168	32.67216	-0.40548	28.4958	-2.41428
	30.25836	2.01804	30.65688	0.09996	32.9022	0.1194	32.8374	-0.45408	28.57356	-3.26316
	Angular Accuracy Statistics (0.000")									
RANGE	18.06624	4.83084	4.06296	4.71744	5.50152	6.48972	0.49248	1.22796	2.08332	2.19996
AVERAGE	30.014874	2.162382	30.29076	0.915468	33.374268	-0.020568	32.773086	-0.609762	28.434564	-3.26397
σ (68% CL)	3.452934344	1.10531196	0.959636081	1.369236461	1.420059569	1.27637587	0.143380332	0.298032684	0.563421688	0.622211322
(95% CL)	6.767751314	2.166411441	1.880886718	2.683703463	2.783316756	2.501696706	0.281025451	0.584144062	1.104306508	1.219534192
	Effect of Angular Accuracy at Target Distance (m)									
RANGE	0.0258	0.0069	0.0058	0.0067	0.0078	0.0093	0.0007	0.0018	0.0030	0.0031
σ (68% CL)	0.0049	0.0016	0.0014	0.0020	0.0020	0.0018	0.0002	0.0004	0.0008	0.0009
(95% CL)	**0.0097**	**0.0031**	**0.0027**	**0.0038**	**0.0040**	**0.0036**	**0.0004**	**0.0008**	**0.0016**	**0.0017**
Target Distance	294.292									

Table 4.8, Observations and Statistical Calculations – Experiment 8

Experiment 8 Observations	S6 AutoLock		S6 Manual		S9 AutoLock		S9 FineLock		S9 Manual	
	HA"	VA"	HA"	VA"	HA"	VA"	HA"	VA"	HA"	VA"
	29.41596	15.26004	26.26344	13.86036	29.92788	15.39936	32.7888	9.5058	30.5046	7.29936
	27.85428	14.71572	29.46456	22.67964	34.46388	13.50396	32.38704	9.04248	30.62124	15.02352
	26.35416	11.98116	30.30372	17.63496	35.07624	12.02004	32.32548	8.91612	29.46132	12.12696
	25.71588	11.31048	27.74088	17.75808	30.29076	13.16376	32.6916	9.97884	30.65688	12.78468
	29.48076	16.5366	28.44072	18.74628	31.3794	15.32484	32.65272	10.1376	30.8124	11.20032
	27.4266	12.20796	28.72584	16.60788	34.12044	11.45628	31.53168	10.14732	30.77352	8.76708
	26.73648	17.41464	28.9332	11.31696	35.71452	15.95664	31.9626	13.0536	30.15792	8.65044
	28.21716	17.08416	27.20952	14.37552	33.5178	12.72636	32.88924	12.52872	31.27572	10.11816
	24.17688	17.96868	27.94824	16.96428	35.21556	9.89136	32.60412	12.5676	31.27572	10.0404
	24.18012	8.60832	27.864	15.3378	32.29632	9.1008	33.3234	14.61852	30.96792	13.67244
	29.62332	13.74048	27.702	15.84	31.47012	9.33084	32.21208	11.42388	29.38356	11.43036
	25.03224	13.20264	28.11024	16.29036	36.57636	13.41	32.34492	11.1582	30.27132	8.0316
	26.12088	12.49308	28.35648	13.04388	33.17436	11.7414	32.2704	13.17996	29.92464	9.49932
	30.54024	15.84324	31.31136	13.75992	32.87304	14.787	31.27572	8.9874	29.18916	5.56272
	28.0098	17.8974	28.80684	14.71896	31.59	10.93464	31.90428	12.46392	29.18916	5.56272
	26.05284	11.37852	26.83692	19.31652	31.69044	12.86244	32.34492	14.34312	29.22804	11.70252
	30.93876	12.94344	27.29052	16.6014	31.38264	12.94668	32.28984	13.74372	30.38796	12.51252
	28.84896	10.71108	27.98712	13.37436	30.72168	15.56136	34.8786	13.10868	29.65572	13.248
	27.40716	11.31048	27.783	15.50628	31.20444	12.62916	32.71104	13.22856	29.65572	13.248
	26.85636	12.49308	27.08316	15.01056	33.52752	13.2804	32.76936	12.82356	28.41804	5.79276
Angular Accuracy Statistics (0.000")										
RANGE	6.76188	9.36036	5.04792	11.36268	6.64848	6.85584	3.60288	5.7024	2.85768	9.4608
AVERAGE	27.449442	13.75506	28.208088	15.9372	32.81067	12.801366	32.507892	11.74788	30.090528	10.313694
σ (68% CL)	1.966794329	2.692274188	1.180876241	2.551735505	1.914300754	2.01511859	0.729406573	1.869883811	0.792520439	2.853303146
(95% CL)	3.854916886	5.276857409	2.314517432	5.00140159	3.752029477	3.949632436	1.429636883	3.66497227	1.55334006	5.592474166
Effect of Angular Accuracy at Target Distance (m)										
RANGE	0.0055	0.0076	0.0041	0.0092	0.0054	0.0055	0.0029	0.0046	0.0023	0.0076
σ (68% CL)	0.0016	0.0022	0.0010	0.0021	0.0015	0.0016	0.0006	0.0015	0.0006	0.0023
(95% CL)	**0.0031**	**0.0043**	**0.0019**	**0.0040**	**0.0030**	**0.0032**	**0.0012**	**0.0030**	**0.0013**	**0.0045**
Target Distance	166.592									

Table 4.9, Observations and Statistical Calculations – Experiment 9

	Experiment 9 Observations									
	S6 AutoLock		S6 Manual		S9 AutoLock		S9 FineLock		S9 Manual	
	HA"	VA"	HA"	VA"	HA"	VA"	HA"	VA"	HA"	VA"
	29.16	13.48572	30.37176	14.17908	31.2498	6.3318	32.6754	6.14712	31.08132	3.78516
	35.5914	17.81112	27.94824	8.67756	36.90036	6.33504	33.06096	6.82752	31.9302	4.67292
	28.70964	12.9576	28.9332	16.68684	34.30188	4.64376	33.09012	15.55608	31.38912	5.13624
	28.9008	9.90876	29.26044	17.54544	33.34608	9.22188	34.51572	10.3818	31.85244	7.95828
	28.68048	11.4186	29.4678	13.64448	33.10308	8.51232	34.30188	7.31676	29.57472	7.9194
	25.32708	10.56	26.9244	12.08604	27.84132	12.747	32.31252	8.20776	29.57472	7.9194
	27.12852	13.46952	29.87928	9.93792	32.52636	7.16448	31.66452	7.48848	30.8124	4.78956
	22.1292	14.41236	28.44072	12.28692	32.3028	3.96984	34.20468	8.45076	28.02924	4.13508
	46.1214	19.94952	28.9332	10.36236	35.00172	5.53476	32.78556	7.73148	28.34028	10.66044
	21.79872	15.26772	28.19448	15.77964	31.38912	10.42392	32.97024	7.97772	32.24124	7.33944
	25.11	10.90668	29.50668	11.17236	32.3514	8.0166	33.84828	5.48616	30.85128	8.30496
	12.879	17.8176	26.05932	10.72848	31.9302	10.0902	34.41852	11.15292	32.24124	5.17512
	26.23428	13.476	27.25164	10.62804	29.20212	8.61276	33.80616	5.68704	30.618	12.59148
	20.40228	10.99416	30.32964	12.8766	31.68396	12.10548	34.01676	5.08116	31.19796	9.15384
	44.70552	14.47392	30.49164	15.0798	32.63976	8.26608	33.48216	6.3966	32.85684	7.53384
	27.2322	10.82568	26.71704	14.67156	31.58028	8.4216	32.96052	8.5188	32.28012	9.9282
	21.91212	15.05388	28.60596	10.62156	32.886	8.95296	32.7078	8.59008	30.8124	12.16704
	30.15468	9.15384	27.45576	11.57736	35.49096	9.00156	32.55876	6.17628	30.96468	11.2404
	30.09636	12.59148	29.0142	17.43528	34.33428	6.13092	33.52104	9.01452	26.52264	11.82036
	23.72328	15.48804	29.26044	12.97704	30.98088	3.91152	33.29424	9.7824	29.96028	11.08488
	Angular Accuracy Statistics (0.000")									
RANGE	33.2424	10.79568	4.43232	8.86788	9.05904	8.83548	2.8512	10.47492	6.3342	8.80632
AVERAGE	27.799848	13.50111	28.652292	12.947718	32.552118	7.919724	33.309792	8.098572	30.656556	8.165802
σ (68% CL)	7.647004449	2.8666512	1.270770661	2.602692853	2.076877237	2.447787164	0.768867339	2.398227201	1.604726569	2.862245081
(95% CL)	14.98812872	5.618636352	2.490710496	5.101277993	4.070679385	4.797662842	1.506979984	4.700525315	3.145264075	5.61000036
	Effect of Angular Accuracy at Target Distance (m)									
RANGE	0.0161	0.0052	0.0022	0.0043	0.0044	0.0043	0.0014	0.0051	0.0031	0.0043
σ (68% CL)	0.0037	0.0014	0.0006	0.0013	0.0010	0.0012	0.0004	0.0012	0.0008	0.0014
(95% CL)	**0.0073**	**0.0027**	**0.0012**	**0.0025**	**0.0020**	**0.0023**	**0.0007**	**0.0023**	**0.0015**	**0.0027**
Target Distance	100.172									

Table 4.10, Observations and Statistical Calculations – Experiment 10

Experiment 10 Observations										
	S6 AutoLock		S6 Manual		S9 AutoLock		S9 FineLock		S9 Manual	
	HA"	VA"	HA"	VA"	HA"	VA"	HA"	VA"	HA"	VA"
	28.36296	4.81776	30.86424	4.66872	34.89804	-2.5824	37.08504	1.8402	33.21	-6.30516
	28.75176	5.1288	28.89432	5.0154	35.7858	-3.74556	35.77608	-3.66456	32.28012	-0.93648
	31.35348	3.90732	30.57588	-1.02396	34.48332	-5.7576	36.67356	-1.95384	33.8256	-3.44748
	30.23244	5.64396	30.20976	1.56156	35.5104	-4.82124	35.36136	-5.20356	31.97232	-5.9196
	28.58976	3.46668	28.56708	1.92768	34.4574	-1.87284	36.63468	-0.27876	31.93344	-0.12648
	30.96468	2.81544	29.71728	-1.50672	36.14544	1.8888	36.66384	1.20192	31.93344	-0.12648
	9.24372	1.40604	28.23984	1.88232	29.48076	6.81684	36.73188	-0.82632	33.36228	0.57012
	28.2042	3.22692	27.94824	0.85848	30.64392	-1.08228	35.97048	-0.25608	31.93344	-3.83304
	32.55552	10.2156	27.66312	2.75388	34.57404	-1.88256	36.44352	1.18248	33.21	0.49236
	36.54396	8.96496	28.60596	2.83812	34.1658	0.0744	35.7858	-0.039	31.62564	-3.48636
	29.63304	7.61388	28.60596	3.36624	54.14364	12.29892	36.207	-2.19684	32.47452	-4.75968
	28.87488	2.63724	28.60596	1.55508	35.35812	-2.88048	35.7372	-0.3792	32.0112	-3.63864
	31.8654	5.73144	27.82836	-0.20748	35.87328	-6.12696	36.1908	0.528	32.35788	-2.2098
	32.89248	6.50256	29.83716	0.3498	35.87004	-3.3438	35.7372	-3.13644	32.74344	-0.78096
	28.2204	3.96564	29.87928	4.64928	35.74368	-3.62892	36.23616	-3.36324	30.8124	-4.2186
	26.45784	2.86728	29.55204	-0.6222	36.95544	-3.24336	36.6444	1.77864	34.02	-3.56088
	29.60388	3.28524	28.81332	6.60624	36.43704	-5.37852	36.44676	-0.64164	31.97232	-3.4086
	26.70732	5.55324	30.456	-0.30468	35.23176	-5.44656	35.964	-1.56828	30.34908	-5.76408
	38.76984	-0.33384	30.37176	3.46668	32.29632	-3.441	35.52984	-3.95292	32.93784	-0.93648
	38.75364	3.35976	30.37176	3.40512	35.29008	-2.00892	35.6076	-3.2142	32.16672	-0.97536
Angular Accuracy Statistics (0.000")										
RANGE	29.52612	10.54944	3.20112	8.11296	24.66288	18.42588	1.72368	7.04376	3.67092	6.87528
AVERAGE	29.82906	4.538796	29.280366	2.061978	35.667216	-1.808202	36.17136	-1.207182	32.356584	-2.668584
σ (68% CL)	6.005947104	2.499728193	1.014891039	2.231052077	4.736140147	4.450932172	0.480605301	2.059935111	0.912975491	2.189853103
(95% CL)	11.77165632	4.899467258	1.989186436	4.372862071	9.282834689	8.723827058	0.94198639	4.037472818	1.789431962	4.292112082
Effect of Angular Accuracy at Target Distance (m)										
RANGE	0.0222	0.0079	0.0024	0.0061	0.0185	0.0139	0.0013	0.0053	0.0028	0.0052
σ (68% CL)	0.0045	0.0019	0.0008	0.0017	0.0036	0.0033	0.0004	0.0015	0.0007	0.0016
(95% CL)	**0.0089**	**0.0037**	**0.0015**	**0.0033**	**0.0070**	**0.0066**	**0.0007**	**0.0030**	**0.0013**	**0.0032**
Target Distance	155.110									

4.4 *Visual Representation of Results*

To aid in the interpretation of the calculated results from Tables 4.1 to 4.10, the effect of angular accuracy at target distance at the 95% confidence level values have been taken from the second last row of the table and been graphed in Figures 4.11 to 4.20 respectively. This visual aid allows for easy comparison against each aiming method within the experiment and easier interpretation of the magnitude of the results. It also proves useful for the comparison of trends in data between different experimental scenarios.

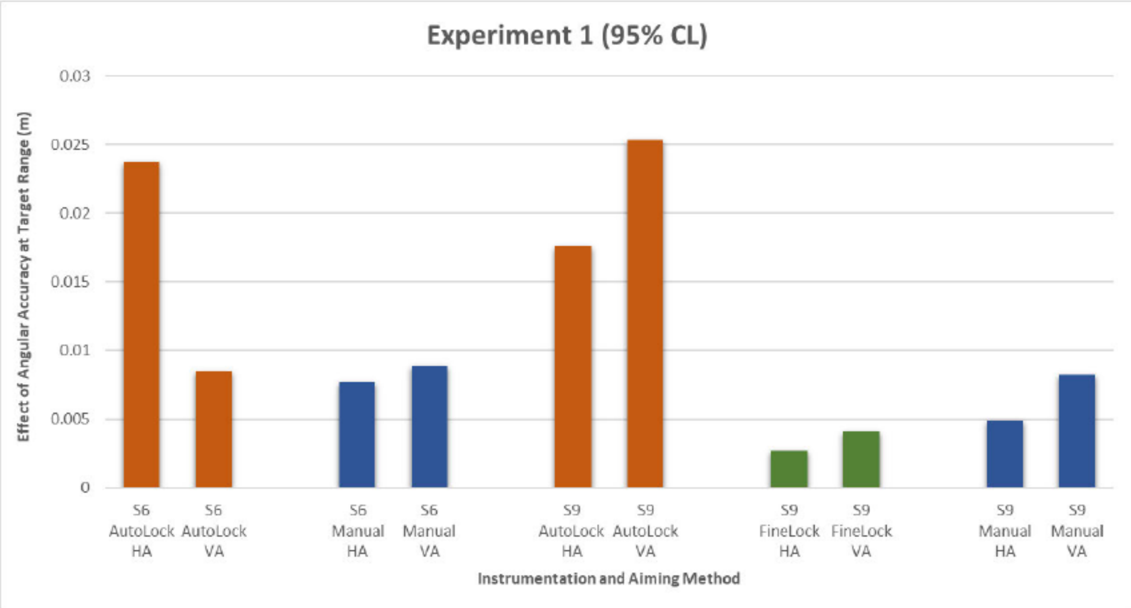

Figure 4.11, Experiment 1 – Accuracy at Target Range 95%CL

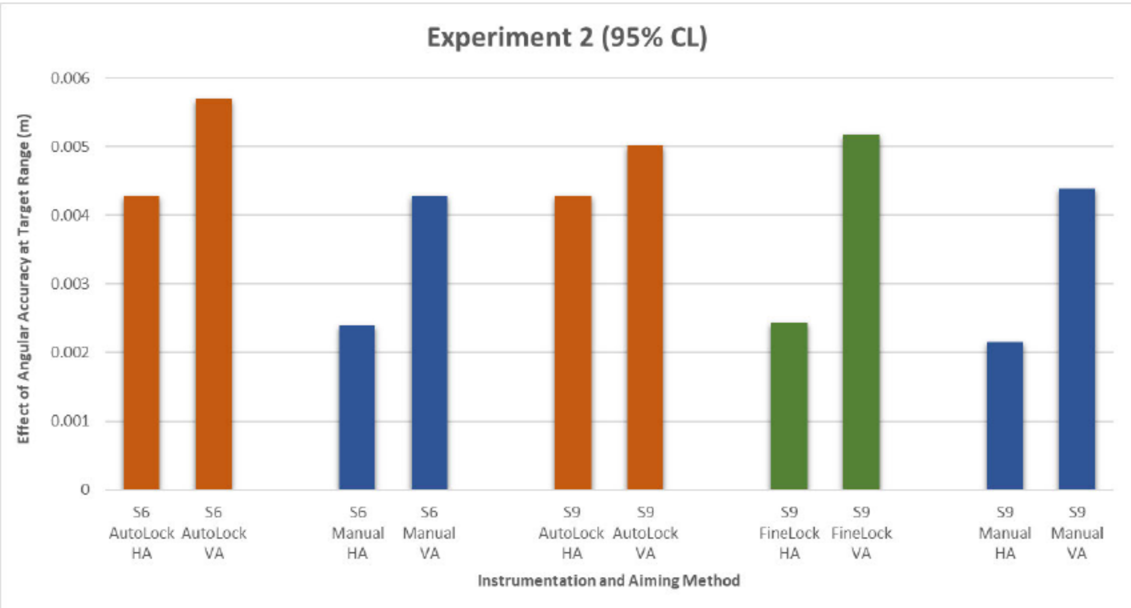

Figure 4.12, Experiment 2 – Accuracy at Target Range 95%CL

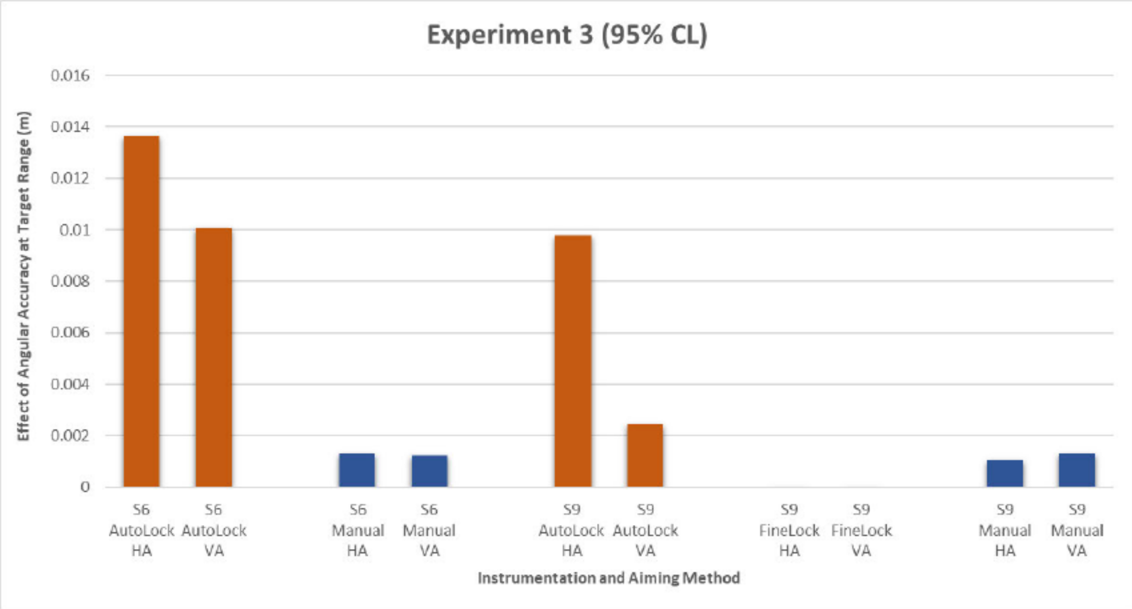

Figure 4.13, Experiment 3 – Accuracy at Target Range 95%CL

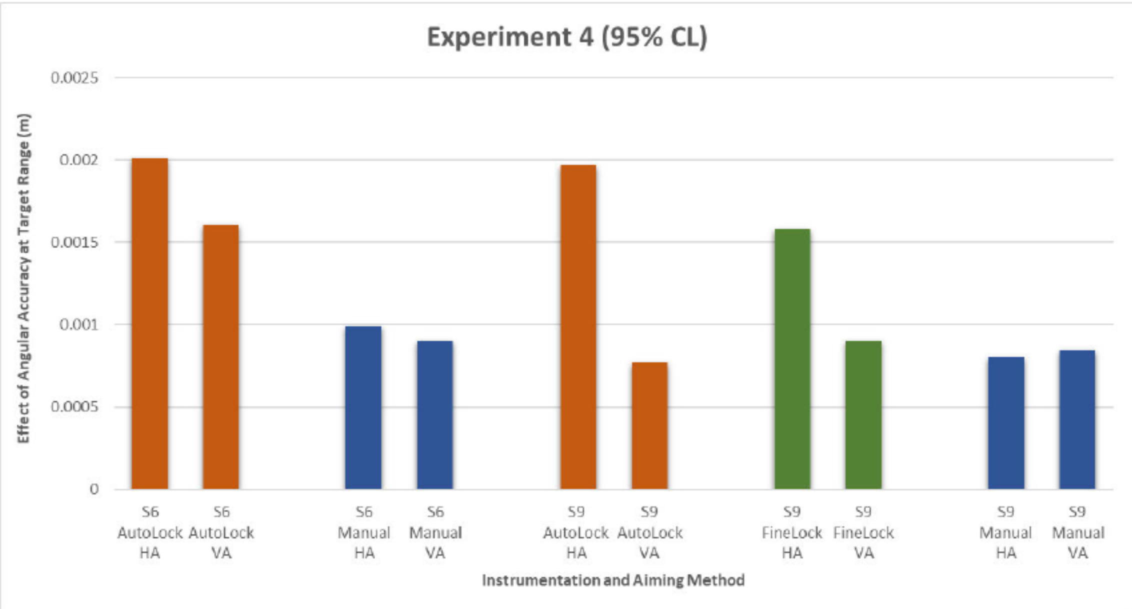

Figure 4.14, Experiment 4 – Accuracy at Target Range 95%CL

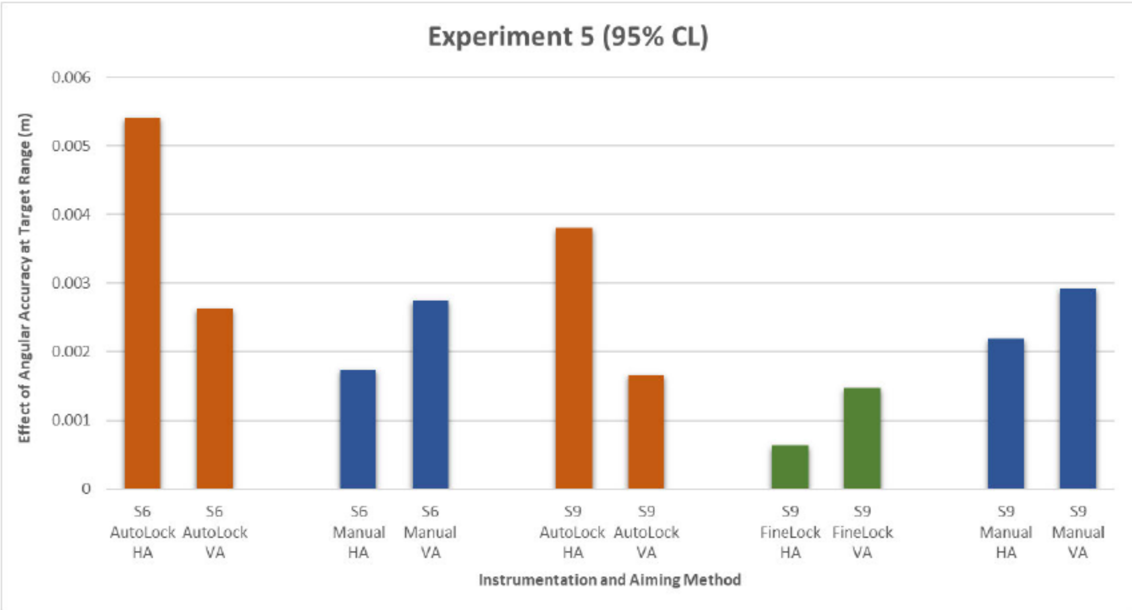

Figure 4.15, Experiment 5 – Accuracy at Target Range 95%CL

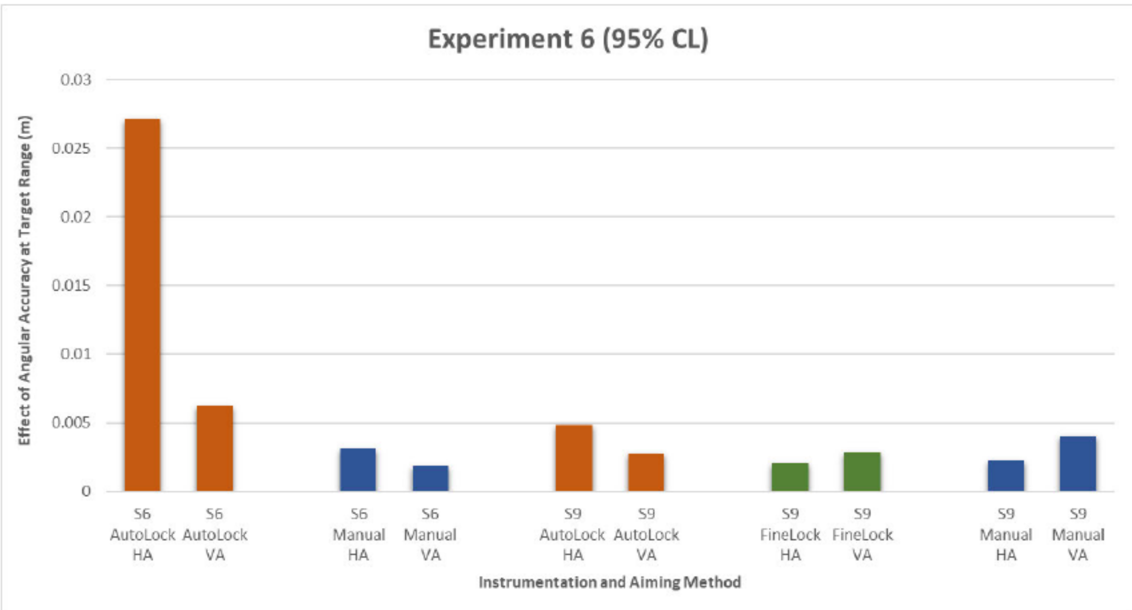

Figure 4.16, Experiment 6 – Accuracy at Target Range 95%CL

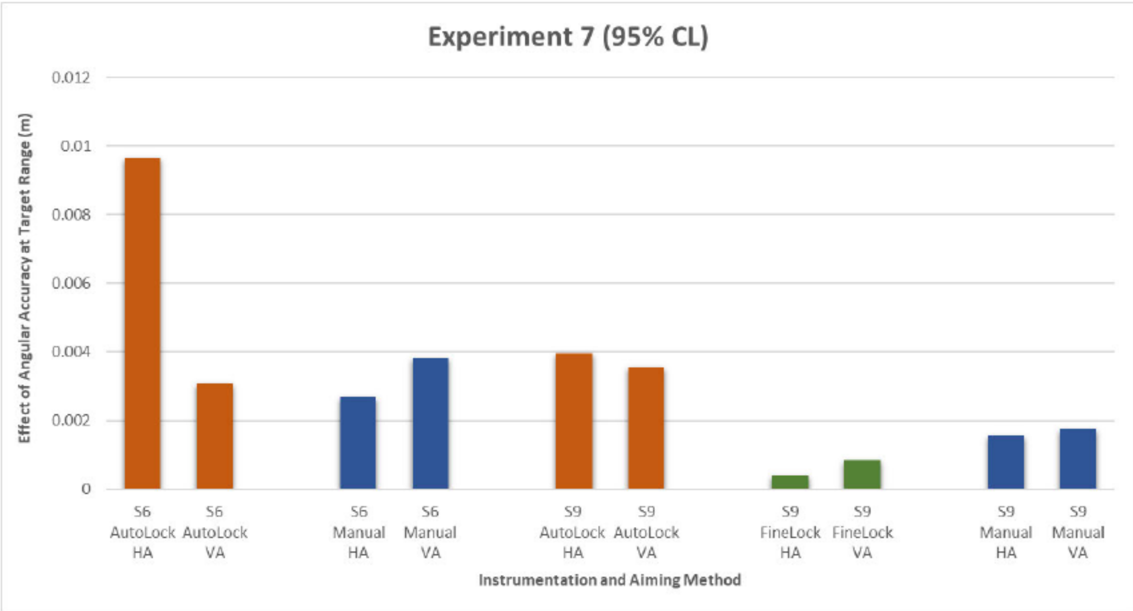

Figure 4.17, Experiment 7 – Accuracy at Target Range 95%CL

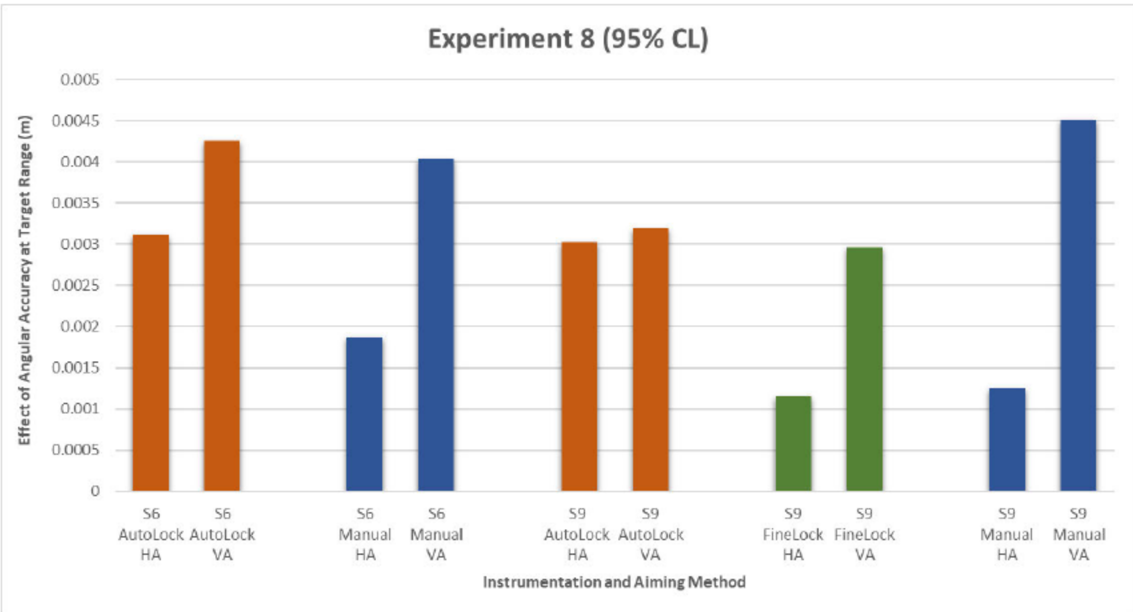

Figure 4.18, Experiment 8 – Accuracy at Target Range 95%CL

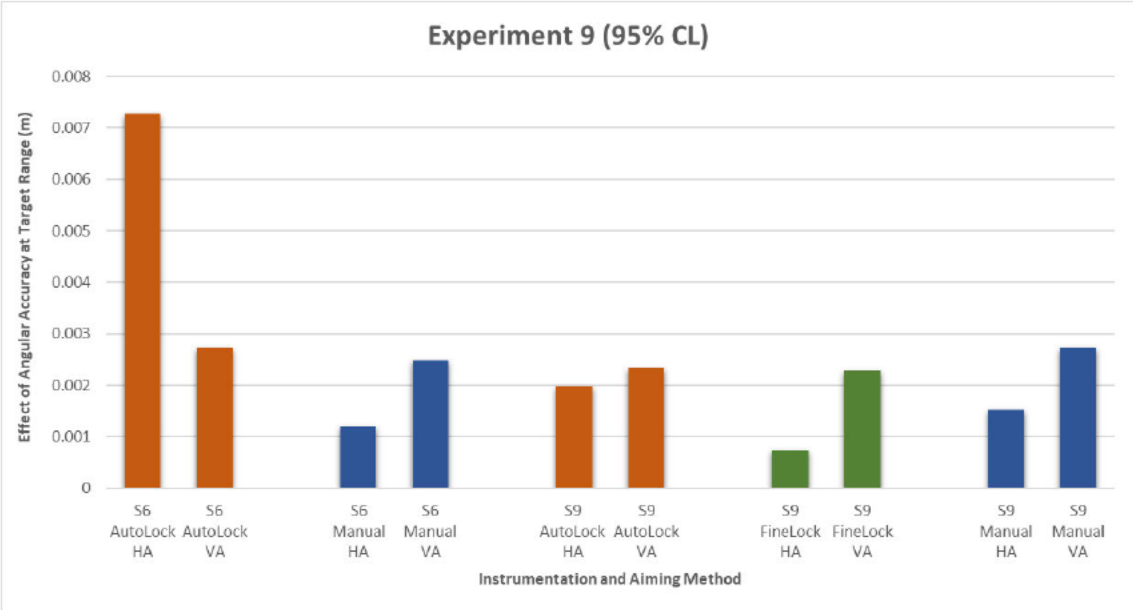

Figure 4.19, Experiment 9 – Accuracy at Target Range 95%CL

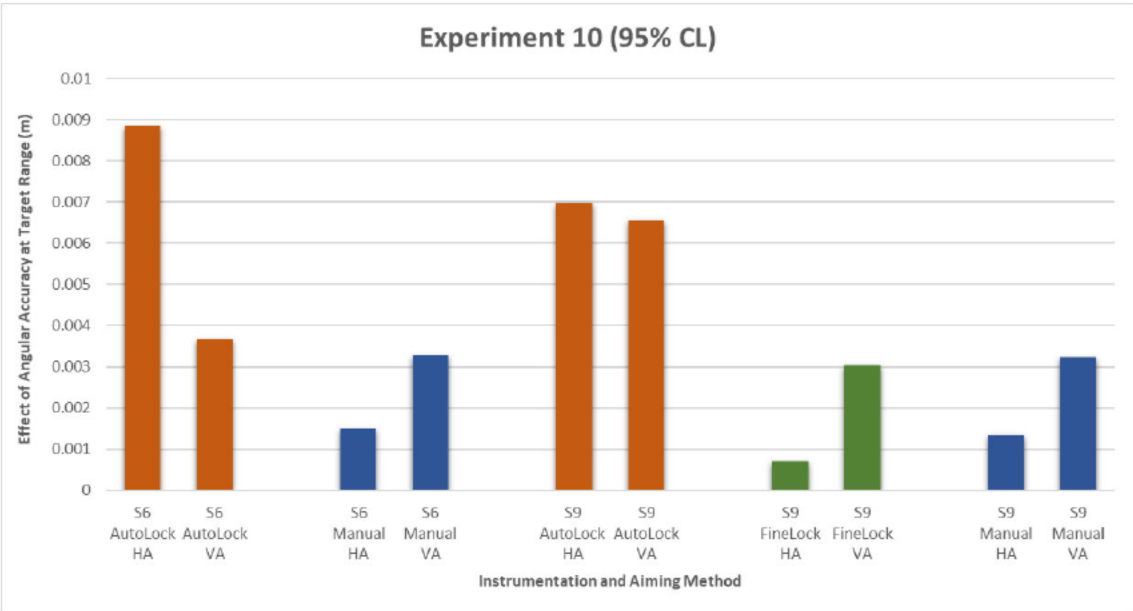

Figure 4.20, Experiment 10 – Accuracy at Target Range 95%CL

4.5 Summary

The successful collection, statistical analysis and representation of result data is evident in this chapter, with the easily interpreted bar graphs. If stringent investigation of all data is possible as all observations and calculations have been recorded in this chapter or attached in Appendix B.

5. Discussion

5.1 Introduction

Each experiment was carried out under a different condition to be able to investigate the results stored by the instruments under a variety of different environments and simulated conditions that could normally be encountered in field while a surveyor establishing survey control. In the following sections of this chapter, the results calculated in Chapter 4 are analysed and interpreted to establish how each survey condition effects the accuracy of the 5 different methods of aiming the total station tested.

5.2 Experiment 1 – Long Range

This experiment was designed to test the absolute limit of the length of an observed line during a standard control survey. A reflective target was placed 471.68m away from the measuring pillar with no physical obstructions along the line of sight. Heat shimmer was not visible by the naked eye but was visible through the eye piece of the instruments. Generally, a distance this far would introduce more heat shimmer visible by eye, but with the survey line passing between to hills most of the line experienced ground clearance of >20m. This allowed the air temperatures to equalize and lessen the effect of heat shimmer.

Figure 4.11 graphs the effect of angular accuracy at the target range to the 95% confidence level. The graph illustrates that both the Trimble S6 3" and the S9 1" instruments measured considerably better in manual operation rather than in AutoLock mode. The S9 1" instrument did perform better in FineLock mode then when operated manually. However, the difference was marginal and could be attributed to the accuracy of the instrument as the variance was less than the manufacturers specification as outlined in Chapter 2.3.

From these results it becomes obvious that when AutoLock software is used in either instrument is significantly more susceptible to the heat shimmer interference outlined in Chapter 2.4 than Manual Aiming and FineLock mode.

The use of instruments with two different levels of angular measurement accuracy allows for the identification of trends between AutoLock mode and manual aiming. This helps to establish if the figures observed in each graph are actually 'aiming errors' or if they might be 'angle measurement errors' from the instrument itself.

From the results obtained during this this experimental scenario the preferred priority of aiming methods that should be used if available are ordered:

1) FineLock
2) Manual Aiming
3) AutoLock

5.3 Experiment 2 – Heat Shimmer

This experiment was designed to test the general length of an observed line during a standard control survey. A reflective target was placed 153.821m away from the measuring pillar with no physical obstructions along the line of sight. Heat shimmer was not visible by the naked eye but was visible through the eye piece of the instruments. If a responsible surveyor had seen the magnitude of the heat shimmer through the eye piece, they would have taken action to try and remedy by choosing another position for the survey target. A surveyor that didn't sight through the eye piece would not have noticed this heat shimmer.

Figure 4.12 graphs the effect of angular accuracy at the target range to the 95% confidence level. The graph illustrates that both the Trimble S6 3" and the S9 1" instruments measured considerably better in manual operation rather than AutoLock mode. The S9 1" instrument didn't perform as well in FineLock mode then when operated manually, the difference was marginal for HA and approximately 0.001m for the VA. From these results it becomes obvious that when AutoLock software is used in either instrument is significantly more susceptible to the heat shimmer interference outlined in Chapter 2.4 than Manual Aiming and FineLock mode.

The difference between the results from the two models of instrumentation is minimal in this experiment. This because the 'angle measurement errors' between each instrument does not make as much of a difference over the shorter observed line.

From the results obtained during this this experimental scenario the preferred priority of aiming methods that should be used if available are ordered:

1) Manual Aiming
2) FineLock
3) AutoLock

5.4 *Experiment 3 – Vegetation*

This experiment was designed to test the aiming performance when surveying through bushland. A reflective target was placed 54.667m away from the measuring pillar with foliage from small undergrowth style trees along the line of sight. Heat shimmer was not visible by the naked eye or through the eye piece of the instruments. By the naked eye foliage along the line was visible but did not appear to be severe. A responsible surveyor would have taken action to clear the line even though AutoLock found the target. When viewing through the eye piece it was very obvious further action was needed to clear the survey line.

Figure 4.13 graphs the effect of angular accuracy at the target range to the 95% confidence level. The graph illustrates that both the Trimble S6 3" and the S9 1" instruments measured outstandingly better in manual operation rather than AutoLock mode. The S9 1" instrument wasn't able to obtain lock in FineLock mode and was excluded from this experiment, this can be seen as a positive as the condition should have really been rectified before a surveyor would attempt to make observations in these conditions. From these results it becomes obvious that when ATR struggles with an intermittent obstruction as outlined in Chapter 2.4. The FineLock system is unable to even take the measurement and the AutoLock software used in either instrument is significantly susceptible to the interrupted noise received from the flickering infrared beam at the CMOS sensor, as outlined in Chapter 2.2.

The difference between the results from the two models of instrumentation is minimal in this experiment. This because the 'angle measurement errors' between each instrument does not make as much of a difference over the shorter observed line.

From the results obtained during this this experimental scenario, the preferred priority of aiming methods that should be used if available are ordered:

1) Manual Aiming
2) AutoLock

5.5 Experiment 4 – Scattered Tall Grass

This experiment was designed to test the aiming performance when surveying through scattered patches of tall thin grass. A reflective target was placed 39.142m away from the measuring pillar with a small thin patch of tall grass along the line of sight. Heat shimmer was not visible by the naked eye or through the eye piece of the instruments. By the naked eye the grass along the line was visible but didn't seem to severe. A responsible surveyor would have taken action to clear the line even though AutoLock found the target. When viewing through the eye piece it was very obvious further action was required to clear the survey line, triggering the surveyor to do so.

Figure 4.14 graphs the effect of angular accuracy at the target range to the 95% confidence level. The graph illustrates that both the Trimble S6 3" and the S9 1" instruments measured better in manual operation rather than AutoLock mode. The S9 1" instrument produced AutoLock VA results only slightly better than VA from FineLock and Manual aiming, the difference between them 0.0001m is insignificant.

The difference between the results from the two models of instrumentation is minimal in this experiment. This because the 'angle measurement errors' between each instrument don't make as much of a difference over the shorter observed line.

From the results obtained during this this experimental scenario, the preferred priority of aiming methods that should be used if available are ordered:

1) Manual Aiming
2) FineLock
3) AutoLock

5.6 Experiment 5 – Night-time

This experiment was designed to test the general length of an observed line during a standard control survey, the exact same setup as in experiment 2 however observations were taken at night so heat shimmer wouldn't affect the observations. A reflective target was placed 153.821m away from the measuring pillar with no physical obstructions along the line of sight. Heat shimmer was not visible by the naked eye or through the eye piece of the instruments, as the observations were taken at night. A light source was used to illuminate the target to allow visibility for manual aiming.

Figure 4.15 graphs the effect of angular accuracy at the target range to the 95% confidence level. The graph illustrates that both the Trimble S6 3" and the S9 1" instruments measured considerably better in manual operation rather than AutoLock mode. The S9 1" instrument performed much better using FineLock mode then when operated manually.

As this experiment was the same as experiment 2 apart from heat shimmer being removed as an interference factor, when we compare the experiments 2 & 5 it proves that heat shimmer certainly does affect the ability of ATR technology. This can be seen by the clear improvement of results once the heat shimmer had been removed. The manually aimed HA observations were only minorly effected when the heat shimmer was removed, however the VA were affected a little more. Overall the heat shimmer proved to have minimal effect on the manual aiming method when compared to the AutoLock or FineLock technology.

From the results obtained during this this experimental scenario, the preferred priority of aiming methods that should be used if available are ordered:

1) FineLock
2) Manual Aiming
3) AutoLock

5.7 *Experiment 6 – Sun Behind Target*

This experiment was designed to test the length of an observed line against the manufacturer's specifications with the exception of excessive amounts of light shining down the eyepiece of the instrument. A reflective target was placed 294.292m away from the measuring pillar with no physical obstructions along the line of sight. Heat shimmer was not visible by the naked eye and no excessive amounts of heat shimmer was visible through the eye piece of the instruments (within standard operating conditions - allowable level of heat shimmer).

Figure 4.16 graphs the effect of angular accuracy at the target range to the 95% confidence level. The graph illustrates that both the Trimble S6 3" and the S9 1" instruments measured considerably better in manual operation rather than AutoLock mode. The S9 1" instrument performed slightly better in FineLock mode then when operated manually, the difference was marginal for HA and only 0.0011m for the VA. The S6 3" instrument produced a terrible result when using AutoLock but had the ability to produce a decent result when operated manually, this is because the 10-year older S6 instrument doesn't have the same quality of CMOS sensor as in the newer S9 unit. This new CMOS imagining sensor allows for better processing from light scatter or excessive glare.

From the results obtained during this this experimental scenario, the preferred priority of aiming methods that should be used if available are ordered:

1) FineLock
2) Manual Aiming
3) AutoLock

5.8 Experiment 7 – Night-time

This experiment was designed to test the length of an observed line against the manufacturer's specifications. The exact same setup as in experiment 6 however observations were taken at night to remove the excessive amounts of light shining down the eyepiece of the instrument. A reflective target was placed 294.292m away from the measuring pillar with no physical obstructions along the line of sight. Heat shimmer was not visible by the naked eye or through the eye piece. A light source was used to illuminate the target to allow visibility for manual aiming.

Figure 4.17 graphs the effect of angular accuracy at the target range to the 95% confidence level. The graph illustrates that both the Trimble S6 3" and the S9 1" instruments measured considerably better in manual operation rather than AutoLock mode. The S9 1" instrument performed significantly better in FineLock mode then when operated manually, and well within the manufacturers specifications. Both the S6 3" and the S9 1" instrument produced better manual aiming results in experiment 7 when comparing experiment 6, this is attributed to the bright sunlight experienced by the surveyor in experiment 6 making it harder to sight the target. Once the excessive sunlight was removed the AutoLock results of the older S6 3" instrument its results improved significantly more than the AutoLock results from the S9 1" instrument as that only made a marginal improvement between experiments. This was to be expected with the older imagining sensor.

From the results obtained during this this experimental scenario, the preferred priority of aiming methods that should be used if available are ordered:

1) FineLock
2) Manual Aiming
3) AutoLock

5.9 Experiment 8 – Rain

This experiment was designed to test the aiming performance when surveying through a light shower of rain. A reflective target was placed 166.592m away from the measuring pillar with a clear line of sight along the line, except for a shower head sprinkler that was positioned to simulate rainfall along the survey line for a length of approximately 30m. Heat shimmer was not visible by the naked eye or through the eye piece of the instruments. In the event of rainfall, generally most survey field operations are put on hold. This experimental scenario tests the results that a surveyor may achieve if the rain starts to fall toward the end of their traverse and the surveyor decides to push on a few more traverse legs to close off the survey traverse before packing up the equipment.

Figure 4.18 graphs the effect of angular accuracy at the target range to the 95% confidence level. The graph illustrates that both the Trimble S6 3" and the S9 1" instruments measured better in manual operation rather than AutoLock mode. In manual mode the S9 1" delivered good results for HA but was the worst performing for VA (only marginally). It is believed that this was from a combination of both the rain physically making the prism harder to view and surveyor fatigue as there had been hundreds of manual sightings from the surveyor during strong and gusty winds present during the observations. The S9 1" instrument performed best in FineLock mode.

From the results obtained during this this experimental scenario, the preferred priority of aiming methods that should be used if available are ordered:

1) FineLock
2) Manual Aiming
3) AutoLock

5.10 Experiment 9 – Reflective Sign

This experiment was designed to test the aiming performance when surveying in close proximity of a reflective street sign. A reflective target was placed 100.172m away from the measuring pillar with a clear line of sight along the line, however a reflective street sign was slightly offline facing the instrument. Heat shimmer was not visible by the naked eye and no excessive amounts of heat shimmer was visible through the eye piece of the instruments (within standard operating conditions - allowable level of heat shimmer).

Figure 4.19 graphs the effect of angular accuracy at the target range to the 95% confidence level. The graph illustrates that both the Trimble S6 3" and the S9 1" instruments measured better in manual operation rather than AutoLock mode. In manual mode the S9 1" delivered good results for HA but was the worst performing for VA (only marginally). It is believed this was due to surveyor fatigue as there had been hundreds of manual sightings from the surveyor during strong and gusty winds present during the observations. The S9 1" instrument performed best in FineLock mode. The S6 3" instrument produced a terrible result when using AutoLock but had the ability to produce a decent result when operated manually. This same trend was noticed in experiment 6 as the 10-year older S6 instrument doesn't have the same quality of CMOS sensor as in the newer S9 unit, that delivers clearer image capture when faced with higher levels of noise (indirect reflected light).

From the results obtained during this this experimental scenario, the preferred priority of aiming methods that should be used if available are ordered:

1) FineLock
2) Manual Aiming
3) AutoLock

5.11 *Experiment 10 – Temporary Construction Fencing*

This experiment was designed to test the aiming performance when surveying through a temporary style wire mesh construction fence. A reflective target was placed 155.110m away from the measuring pillar behind a standard temporary construction fence. Heat shimmer was not visible by the naked eye and no excessive amounts of heat shimmer was visible through the eye piece of the instruments (within standard operating conditions - allowable level of heat shimmer). By the naked eye, it was not obvious that the survey assistant may have setup the target behind the construction fencing, however it was obvious through the eye piece and responsible surveyor would have taken action to clear the line even though AutoLock found the target.

Figure 4.20 graphs the effect of angular accuracy at the target range to the 95% confidence level. The graph illustrates that both the Trimble S6 3" and the S9 1" instruments measured better in manual operation rather than AutoLock mode. The S9 1" instrument performed best in FineLock mode.

From the results obtained during this this experimental scenario, the preferred priority of aiming methods that should be used if available are ordered:

1) FineLock
2) Manual Aiming
3) AutoLock

5.12 Summary

Throughout experiments and data analysis some distinct trends became clear; these have been summarized below.

- 100% of the time HA S6 Manual aiming performed better than AutoLock.
- 85% of the time VA S6 Manual aiming performed better than AutoLock.
  (In the cases were AutoLock performed better then Manual Aiming the difference was marginal in comparison, and could be scored as a tie)
- 100% of the time HA S9 Manual aiming performed better than AutoLock.
- 75% of the time VA S9 Manual aiming performed better than AutoLock.
  (In the cases were AutoLock performed better then Manual Aiming the difference was marginal in comparison, and could be scored as a tie)
- S9 AutoLock generally better than S6 AutoLock.
- 78% of the time both HA and VA of S9 FineLock is better than AutoLock.
  (In the cases were AutoLock performed better then Manual Aiming the difference was marginal in comparison, and could be scored as a tie)
- Averaging all of the experimental results we are able to generalise the accuracy's achieved at the 95% CL from each method of aiming to confirm the accuracy achieved from each of the methods of aiming at the survey prism. This data is taken from multiple different experimental scenarios and is only used as a gross check for the discussion outlined earlier throughout this chapter.

S9 FineLock is:	+/- HA 0.0014m & VA 0.0026m
S9 Manual Aiming is:	+/- HA 0.0018m & VA 0.0034m
S9 AutoLock is:	+/- HA 0.0058m & VA 0.0054m
S6 Manual Aiming is:	+/- HA 0.0025m & VA 0.0034m
S6 AutoLock is:	+/- HA 0.0105m & VA 0.0049m

Each of the 10 experiments were carried out under a different condition to be able to investigate the accuracy of the results obtained from the instruments using the possible methods of aiming the total station. The results were thoroughly analysed and compared between different methods of aiming and between experiments to successfully establish trends of how each method of aiming is affected by atmospheric conditions, obstructions and user errors that may have arisen from manual aiming.

6. Conclusion

This project was designed to research the most accurate method of aiming a total station at a reflective survey target in an effort to increase the integrity of control establishment surveys. Through research, it was identified that the key sources of error that could affect aiming were, heat shimmer, obstructions, excessive light or reflections from other sources then the survey target. Experiments were successfully designed that tested the repeatability of the observations stored by the total station under various simulated conditions. These observations were then statistically analysed to interpret each method of aiming and analysis trends between different methods of aiming and experimental conditions.

It is obvious from these results that manually aiming a total station to the target will provide a more accurate result then relying on AutoLock technology irrelevant of the accuracy of the total station being used. This is most evident with AutoLock producing HA results on average 4 times less accurate then manual aiming, and VA results 1.5 times less accurate. Furthermore, the use of the total station by manually sighting also requires the surveyor to observe the line, intern allowing them to identify any less then ideal observation conditions that may affect accuracy. The surveyor has the opportunity to remedy any issues that may not have been obvious when using AutoLock as often the eye piece isn't checked when using AutoLock as common practice.

FineLock technology generally is more accurate then Manually Aiming but degrades and performs marginally worse when the surveying conditions become less ideal. The difference between the two methods of aiming is deemed insignificant in these experiments with on average FineLock producing HA results 0.0004m better then manually aiming, and VA results 0.0008m better. These marginal differences could be furthered as the surveyor must view through the eye piece to roughly aim to the target before FineLock takes over, this forces the surveyor to examine the observation line, given them the opportunity to remedy any conditions that may diminish the accuracy of the survey. If the standard operating conditions of a responsible surveyor are present FineLock is proven to provide the best aiming accuracies compared to AutoLock and manual aiming.

7. Recommendations

Based on the findings from this research project, it is recommended that the Trimble FineLock Automatic Target Recognition system should be used as the primary method of aiming a total station during the conventional establishment of survey control. If Trimble FineLock is not available on the total station platform the surveyor has access to, it is recommended that the surveyor should Manually Aim the total station during the conventional establishment of survey control. This paper does not advise the use of Trimble AutoLock in anyway during the conventional establishment of survey control.

Following the recommendation set in this paper, surveyors should ensure they take every step possible to increase the accuracy of their aiming during the establishment of a survey control network.

This report has thoroughly investigated and made specific recommendations for the method of aiming a Trimble Total Station, however there are many other brands and models of total station that have not been tested. These other total stations may operate and react differently to operating conditions when compared to the Trimble branded instruments, it is advised that the testing methodology from this paper be applied to any instrumentation before reliance on the particular brands automatic target recognition system.

8. References

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Work Health and Safety Act 2011 (QLD)

9. Appendix A – Project Specification

ENG4111/4112 Research Project

Project Specification

For: Aleksandar Lazarevic

Title: Assessment of Automatic Target Recognition Against Manual Aiming in Conventional Establishment of Survey Control

Major: Surveying

Supervisor: Jessica Smith

Enrolment: ENG4111-EXT S1,2019
ENG4112-EXT S2,2019

Project Aim: To research, test and evaluate the different methods available for aiming a total station at a target for use in establishing survey control in various site conditions.

Programme: Version 2, 20th March 2019

1. Research the science behind automatic target recognition, How it works and its benefits and limitations.
2. Investigate what the survey standards for establishing survey control are using an automatic total station.
3. Design and plan for a set of experiments that will fully test the accuracy and limitations of each method of survey.
4. Analyse the data from these experiments to test each method of aiming within each simulated environment.
5. Evaluate each method of aiming the survey instrument to clearly identify which method is more accurate.

If time and resources permit:

6. Undertake a survey of people within the surveying industry to identify what methods are most common practice for various types of survey.
7. Design a new standard operation procedure to be used by surveyors identifying what methods should be used for aiming during different types of surveys.

10. Appendix B – Observed Raw Data from Total Station

EXPERIMENT 1

From Point ID	To Point ID	H. Angle	V. Angle	H. Distance	V. Distance
1	100	0°00'30.831840000"	Z89°20'33.964282069"	471.64798	5.42551
1	101	0°00'32.419440000"	Z89°20'32.972888544"	471.64695	5.42777
1	102	0°00'31.936680000"	Z89°20'32.490150997"	471.64721	5.42888
1	103	0°00'33.067440000"	Z89°20'33.786090439"	471.64772	5.42592
1	104	0°00'55.161000000"	Z89°20'38.600505673"	471.64875	5.41492
1	105	0°00'32.908680000"	Z89°20'33.893005787"	471.6463	5.42566
1	106	0°00'35.351640000"	Z89°20'38.995767709"	471.64674	5.41399
1	107	0°00'30.676320000"	Z89°20'32.593826480"	471.64585	5.42862
1	108	0°00'31.807080000"	Z89°20'34.796923450"	471.64707	5.4236
1	109	0°00'33.187320000"	Z89°20'33.164039649"	471.64687	5.42733
1	110	0°00'31.337280000"	Z89°20'33.662976404"	471.64677	5.42619
1	111	0°00'30.724920000"	Z89°20'33.300113347"	471.64668	5.42702
1	112	0°00'31.865400000"	Z89°20'34.502097286"	471.6467	5.42427
1	113	0°00'32.662440000"	Z89°20'34.343344400"	471.64794	5.42465
1	114	0°00'31.334040000"	Z89°20'34.106835481"	471.64772	5.42518
1	115	0°00'32.114880000"	Z89°20'32.885412657"	471.64681	5.42797
1	116	0°00'35.134560000"	Z89°20'31.485797538"	471.64848	5.43119
1	117	0°00'34.771680000"	Z89°20'33.646776848"	471.6481	5.42624
1	118	0°00'35.746920000"	Z89°20'36.186818681"	471.64686	5.42042
1	119	0°00'30.676320000"	Z89°20'32.593826480"	471.64585	5.42862
1	120	0°00'30.449520000"	Z89°20'35.684641482"	471.6495	5.4216
1	121	0°00'30.329640000"	Z89°20'34.080916514"	471.64847	5.42525
1	122	0°00'30.287520000"	Z89°20'35.357417081"	471.64806	5.42233
1	123	0°00'31.560840000"	Z89°20'37.447119369"	471.64915	5.41756
1	124	0°00'28.810080000"	Z89°20'38.513029852"	471.64833	5.41512
1	125	0°00'29.629800000"	Z89°20'34.080916807"	471.64722	5.42524
1	126	0°00'30.494880000"	Z89°20'35.026952406"	471.64843	5.42309
1	127	0°00'31.926960000"	Z89°20'33.918923965"	471.64892	5.42563
1	128	0°00'32.173200000"	Z89°20'31.417760824"	471.648	5.43134
1	129	0°00'34.350480000"	Z89°20'33.909204668"	471.64785	5.42564
1	130	0°00'31.638600000"	Z89°20'37.774344317"	471.64826	5.4168
1	131	0°00'32.665680000"	Z89°20'36.996780624"	471.64807	5.41858
1	132	0°00'31.845960000"	Z89°20'33.261235448"	471.64545	5.42709
1	133	0°00'34.554600000"	Z89°20'35.150066874"	471.64753	5.4228
1	134	0°00'34.269480000"	Z89°20'33.261235027"	471.64725	5.42711
1	135	0°00'33.777000000"	Z89°20'32.810896104"	471.64693	5.42814
1	136	0°00'31.382640000"	Z89°20'35.477291286"	471.64893	5.42206
1	137	0°00'34.269480000"	Z89°20'36.873666383"	471.648	5.41886
1	138	0°00'33.485400000"	Z89°20'31.744985634"	471.6477	5.43059
1	139	0°00'32.992920000"	Z89°20'33.180238683"	471.64777	5.4273
1	140	0°00'29.435400000"	Z89°20'26.878732318"	471.64897	5.44173
1	141	0°00'48.470400000"	Z89°20'50.192685902"	471.64529	5.38837
1	142	0°00'31.748760000"	Z89°20'28.887438639"	471.64897	5.43714
1	143	0°00'31.437720000"	Z89°20'28.780523699"	471.64866	5.43738
1	144	0°00'30.566160000"	Z89°20'26.710260270"	471.64856	5.44211
1	145	0°00'32.393520000"	Z89°20'27.805329198"	471.64857	5.43961
1	146	0°00'33.880680000"	Z89°20'25.265287666"	471.64852	5.44541
1	147	0°00'34.107480000"	Z89°20'23.133467184"	471.64811	5.45028
1	148	0°00'31.133160000"	Z89°20'24.967221646"	471.64819	5.44609
1	149	0°00'35.034120000"	Z89°20'24.024425660"	471.64799	5.44825
1	150	0°00'32.471280000"	Z89°20'26.188644566"	471.64869	5.4433

1	151	0°00'32.004720000"	Z89°20'26.671382130"	471.64836	5.4422
1	152	0°00'31.350240000"	Z89°20'24.474764660"	471.64798	5.44722
1	153	0°00'30.954960000"	Z89°20'26.564467199"	471.64801	5.44244
1	154	0°00'33.346080000"	Z89°20'24.879745515"	471.64908	5.4463
1	155	0°00'30.592080000"	Z89°20'28.080716443"	471.6482	5.43897
1	156	0°00'32.059800000"	Z89°20'26.117367764"	471.64923	5.44347
1	157	0°00'31.191480000"	Z89°20'26.545027930"	471.64876	5.44249
1	158	0°00'33.073920000"	Z89°20'24.970461418"	471.64852	5.44609
1	159	0°00'30.980880000"	Z89°20'23.441252671"	471.64879	5.44959
1	160	0°00'31.473360000"	Z89°20'26.240482162"	471.64863	5.44318
1	161	0°00'31.415040000"	Z89°20'27.448945830"	471.64852	5.44042
1	162	0°00'31.777920000"	Z89°20'27.516982492"	471.64922	5.44027
1	163	0°00'32.004720000"	Z89°20'25.841980719"	471.64875	5.4441
1	164	0°00'31.797360000"	Z89°20'26.172445294"	471.64881	5.44334
1	165	0°00'30.462480000"	Z89°20'27.066643636"	471.64862	5.4413
1	166	0°00'32.241240000"	Z89°20'27.782650183"	471.64888	5.43966
1	167	0°00'31.671000000"	Z89°20'26.097928910"	471.64821	5.44351
1	168	0°00'31.502520000"	Z89°20'27.944642731"	471.64844	5.43929
1	169	0°00'32.587920000"	Z89°20'27.332311249"	471.64861	5.44069
1	170	0°00'31.327560000"	Z89°20'26.097928762"	471.64884	5.44351
1	171	0°00'31.023000000"	Z89°20'25.511516149"	471.64867	5.44485
1	172	0°00'31.709880000"	Z89°20'25.411080888"	471.64844	5.44508
1	173	0°00'31.573800000"	Z89°20'25.589272440"	471.64902	5.44468
1	174	0°00'31.453920000"	Z89°20'26.120607700"	471.64886	5.44346
1	175	0°00'30.443040000"	Z89°20'27.727572776"	471.64878	5.43979
1	176	0°00'32.655960000"	Z89°20'28.122834457"	471.64829	5.43888
1	177	0°00'30.792960000"	Z89°20'26.930569898"	471.64898	5.44161
1	178	0°00'31.936680000"	Z89°20'28.113114833"	471.64862	5.4389
1	179	0°00'32.046840000"	Z89°20'27.047204533"	471.64866	5.44134
1	180	0°00'29.613600000"	Z89°20'29.477090994"	471.6496	5.43579
1	181	0°00'28.531440000"	Z89°20'29.554847545"	471.64884	5.43561
1	182	0°00'28.764720000"	Z89°20'29.668242272"	471.64877	5.43535
1	183	0°00'30.848040000"	Z89°20'27.737292256"	471.64906	5.43977
1	184	0°00'28.842480000"	Z89°20'30.750351922"	471.64828	5.43287
1	185	0°00'31.389120000"	Z89°20'26.580666368"	471.64833	5.4424
1	186	0°00'30.384720000"	Z89°20'31.521435758"	471.64915	5.43111
1	187	0°00'30.812400000"	Z89°20'26.237242281"	471.64877	5.44319
1	188	0°00'29.228040000"	Z89°20'28.702767227"	471.64907	5.43756
1	189	0°00'30.886920000"	Z89°20'26.771817443"	471.64837	5.44197
1	190	0°00'30.345840000"	Z89°20'29.629364184"	471.64835	5.43543
1	191	0°00'31.120200000"	Z89°20'26.078489659"	471.64888	5.44356
1	192	0°00'31.159080000"	Z89°20'28.819401766"	471.64917	5.43729
1	193	0°00'29.730240000"	Z89°20'29.862633314"	471.64832	5.4349
1	194	0°00'30.345840000"	Z89°20'27.082842885"	471.6486	5.44126
1	195	0°00'30.812400000"	Z89°20'26.619544452"	471.64877	5.44232
1	196	0°00'28.725840000"	Z89°20'24.222056299"	471.64861	5.4478
1	197	0°00'30.695760000"	Z89°20'28.394981541"	471.64925	5.43826
1	198	0°00'31.275720000"	Z89°20'29.901511198"	471.64961	5.43482
1	199	0°00'32.743440000"	Z89°20'28.974914585"	471.64886	5.43693

EXPERIMENT 2

From Point ID	To Point ID	H. Angle	V. Angle	H. Distance	V. Distance
1	200	0°00'30.906360000"	Z99°53'36.254040000"	151.55504	-26.48098
1	201	0°00'30.971160000"	Z99°53'40.083720000"	151.55334	-26.48359
1	202	0°00'32.740200000"	Z99°53'37.948560000"	151.55419	-26.48212
1	203	0°00'29.960280000"	Z99°53'35.133000000"	151.55491	-26.48011
1	204	0°00'33.359040000"	Z99°53'33.911520000"	151.55451	-26.47912
1	205	0°00'30.676320000"	Z99°53'39.131160000"	151.5536	-26.48291
1	206	0°00'31.123440000"	Z99°53'35.074680000"	151.55438	-26.47998
1	207	0°00'33.958440000"	Z99°53'35.674080000"	151.5551	-26.48055
1	208	0°00'33.132240000"	Z99°53'35.029320000"	151.55471	-26.48
1	209	0°00'25.903800000"	Z99°53'35.674080000"	151.55384	-26.48033
1	210	0°00'31.969080000"	Z99°53'28.708080000"	151.55507	-26.47528
1	211	0°00'34.152840000"	Z99°53'28.818240000"	151.55529	-26.4754
1	212	0°00'22.365720000"	Z99°53'42.815040000"	151.55402	-26.48577
1	213	0°00'27.750600000"	Z99°53'42.931680000"	151.55312	-26.4857
1	214	0°00'32.257440000"	Z99°53'34.971000000"	151.55359	-26.47976
1	215	0°00'30.177360000"	Z99°53'31.922160000"	151.5557	-26.47782
1	216	0°00'28.077840000"	Z99°53'36.033720000"	151.55618	-26.48101
1	217	0°00'33.828840000"	Z99°53'30.865920000"	151.55448	-26.47681
1	218	0°00'30.028320000"	Z99°53'37.524120000"	151.5542	-26.4818
1	219	0°00'31.201200000"	Z99°53'33.072360000"	151.55514	-26.47859
1	220	0°00'26.963280000"	Z99°53'29.407920000"	151.55615	-26.47599
1	221	0°00'30.365280000"	Z99°53'27.684240000"	151.55622	-26.4747
1	222	0°00'30.449520000"	Z99°53'26.193840000"	151.55596	-26.47353
1	223	0°00'29.710800000"	Z99°53'28.205880000"	151.55586	-26.47503
1	224	0°00'29.179440000"	Z99°53'28.873320000"	151.55623	-26.4756
1	225	0°00'29.208600000"	Z99°53'32.528040000"	151.55523	-26.4782
1	226	0°00'29.879280000"	Z99°53'32.197560000"	151.55409	-26.47775
1	227	0°00'28.560600000"	Z99°53'31.497720000"	151.55583	-26.47752
1	228	0°00'30.326400000"	Z99°53'26.372040000"	151.55588	-26.47365
1	229	0°00'29.957040000"	Z99°53'29.365800000"	151.55464	-26.4757
1	230	0°00'30.984120000"	Z99°53'29.161680000"	151.55615	-26.47581
1	231	0°00'26.470800000"	Z99°53'31.280640000"	151.5551	-26.47723
1	232	0°00'31.395600000"	Z99°53'33.879120000"	151.55524	-26.47922
1	233	0°00'28.725840000"	Z99°53'29.200560000"	151.55583	-26.47578
1	234	0°00'33.320160000"	Z99°53'31.646760000"	151.555	-26.47749
1	235	0°00'29.999160000"	Z99°53'33.020520000"	151.55426	-26.4784
1	236	0°00'32.665680000"	Z99°53'31.692120000"	151.55611	-26.47772
1	237	0°00'31.476600000"	Z99°53'35.259360000"	151.55513	-26.48025
1	238	0°00'30.656880000"	Z99°53'34.251720000"	151.55467	-26.4794
1	239	0°00'29.626560000"	Z99°53'37.122360000"	151.55482	-26.4816
1	240	0°00'32.445360000"	Z99°53'27.956400000"	151.55699	-26.42504
1	241	0°00'31.988520000"	Z99°53'24.538200000"	151.55682	-26.42242
1	242	0°00'33.644160000"	Z99°53'28.494240000"	151.55648	-26.42536
1	243	0°00'31.852440000"	Z99°53'28.248000000"	151.55666	-26.4252
1	244	0°00'32.866560000"	Z99°53'32.952480000"	151.55591	-26.42864
1	245	0°00'30.355560000"	Z99°53'31.662960000"	151.55605	-26.42768
1	246	0°00'30.566160000"	Z99°53'35.985120000"	151.55563	-26.43088
1	247	0°00'26.256960000"	Z99°53'32.615520000"	151.55567	-26.42834
1	248	0°00'35.688600000"	Z99°53'27.483360000"	151.55648	-26.42459
1	249	0°00'36.790200000"	Z99°53'31.238520000"	151.55589	-26.42733
1	250	0°00'29.610360000"	Z99°53'35.758320000"	151.55545	-26.43068

1	251	0°00'31.982040000"	Z99°53'31.857360000"	151.55575	-26.42778
1	252	0°00'27.993600000"	Z99°53'34.520640000"	151.55567	-26.42978
1	253	0°00'33.103080000"	Z99°53'30.626160000"	151.55611	-26.42691
1	254	0°00'27.705240000"	Z99°53'31.083000000"	151.55618	-26.42727
1	255	0°00'28.294920000"	Z99°53'23.724960000"	151.55701	-26.42184
1	256	0°00'34.771680000"	Z99°53'27.979080000"	151.55638	-26.42495
1	257	0°00'27.449280000"	Z99°53'31.488000000"	151.55537	-26.42743
1	258	0°00'34.619400000"	Z99°53'34.954800000"	151.55532	-26.43005
1	259	0°00'31.599720000"	Z99°53'28.983480000"	151.55622	-26.42569
1	260	0°00'31.457160000"	Z99°53'33.807840000"	151.55607	-26.42931
1	261	0°00'31.638600000"	Z99°53'26.401200000"	151.55681	-26.42383
1	262	0°00'31.625640000"	Z99°53'26.579400000"	151.55695	-26.42399
1	263	0°00'33.171120000"	Z99°53'26.022120000"	151.55718	-26.42361
1	264	0°00'31.210920000"	Z99°53'31.296840000"	151.55678	-26.42753
1	265	0°00'34.719840000"	Z99°53'21.330600000"	151.55759	-26.42013
1	266	0°00'30.028320000"	Z99°53'25.192680000"	151.55755	-26.42305
1	267	0°00'31.845960000"	Z99°53'21.696720000"	151.55775	-26.42043
1	268	0°00'33.294240000"	Z99°53'26.022120000"	151.55707	-26.42359
1	269	0°00'33.388200000"	Z99°53'24.214200000"	151.5572	-26.42224
1	270	0°00'33.874200000"	Z99°53'22.127640000"	151.55777	-26.42076
1	271	0°00'33.806160000"	Z99°53'23.618040000"	151.55751	-26.42185
1	272	0°00'35.743680000"	Z99°53'23.190360000"	151.55704	-26.42144
1	273	0°00'31.113720000"	Z99°53'25.114920000"	151.55733	-26.42295
1	274	0°00'32.432400000"	Z99°53'27.988800000"	151.55656	-26.42499
1	275	0°00'31.107240000"	Z99°53'29.336640000"	151.55642	-26.42599
1	276	0°00'30.277800000"	Z99°53'28.789080000"	151.55647	-26.42558
1	277	0°00'29.422440000"	Z99°53'32.952480000"	151.55598	-26.42865
1	278	0°00'32.727240000"	Z99°53'29.132520000"	151.55717	-26.42596
1	279	0°00'30.219480000"	Z99°53'25.652760000"	151.55718	-26.42333
1	280	0°00'28.644840000"	Z99°53'26.728440000"	151.55691	-26.4241
1	281	0°00'27.410400000"	Z99°53'26.070720000"	151.55735	-26.42368
1	282	0°00'24.202800000"	Z99°53'25.957320000"	151.55743	-26.4236
1	283	0°00'27.063720000"	Z99°53'28.892760000"	151.55721	-26.42579
1	284	0°00'28.644840000"	Z99°53'24.564120000"	151.55776	-26.42261
1	285	0°00'28.955880000"	Z99°53'19.623120000"	151.5583	-26.41896
1	286	0°00'28.453680000"	Z99°53'19.082040000"	151.55764	-26.41844
1	287	0°00'29.921400000"	Z99°53'26.226240000"	151.5572	-26.42377
1	288	0°00'28.492560000"	Z99°53'26.845080000"	151.55675	-26.42416
1	289	0°00'27.527040000"	Z99°53'26.342880000"	151.55714	-26.42385
1	290	0°00'28.800360000"	Z99°53'24.875160000"	151.55739	-26.42278
1	291	0°00'30.345840000"	Z99°53'25.182960000"	151.55732	-26.423
1	292	0°00'27.410400000"	Z99°53'30.668280000"	151.55653	-26.42701
1	293	0°00'27.951480000"	Z99°53'24.706680000"	151.5573	-26.42264
1	294	0°00'27.449280000"	Z99°53'23.096400000"	151.55736	-26.42143
1	295	0°00'25.284960000"	Z99°53'28.390560000"	151.55688	-26.42535
1	296	0°00'26.947080000"	Z99°53'23.754120000"	151.55715	-26.42189
1	297	0°00'28.917000000"	Z99°53'19.529160000"	151.55798	-26.41883
1	298	0°00'29.535840000"	Z99°53'23.754120000"	151.55734	-26.42192
1	299	0°00'28.917000000"	Z99°53'24.603000000"	151.55762	-26.42261

EXPERIMENT 3

From Point ID	To Point ID	H. Angle	V. Angle	H. Distance	V. Distance
1	300	0°00'33.546960000"	Z95°03'46.454760000"	54.45158	-4.82394
1	301	0°00'23.619600000"	Z95°03'41.909040000"	54.45346	-4.82289
1	302	0°00'35.196120000"	Z95°03'46.121040000"	54.44523	-4.82329
1	303	0°00'46.367640000"	Z95°04'01.358760000"	54.45028	-4.82779
1	304	0°02'01.882320000"	Z95°03'27.526680000"	54.44973	-4.81874
1	305	0°00'24.533280000"	Z95°03'47.669760000"	54.45091	-4.8242
1	306	0°00'34.820280000"	Z95°03'39.051360000"	54.45151	-4.82196
1	307	0°00'20.868840000"	Z95°03'26.804160000"	54.45099	-4.81866
1	308	0°00'36.521280000"	Z95°03'35.503560000"	54.45335	-4.82118
1	309	0°00'30.912840000"	Z95°03'46.833840000"	54.45199	-4.82407
1	310	0°00'36.019080000"	Z95°03'40.781520000"	54.45195	-4.82246
1	311	0°00'29.056320000"	Z95°03'46.075680000"	54.45181	-4.82386
1	312	0°00'26.626320000"	Z95°03'43.470720000"	54.45029	-4.82303
1	313	0°00'10.568880000"	Z95°03'42.732000000"	54.45113	-4.82291
1	314	0°00'20.564280000"	Z95°04'22.976040000"	54.44922	-4.83345
1	315	0°00'47.180880000"	Z95°03'50.922720000"	54.45305	-4.82526
1	316	0°01'19.749360000"	Z95°02'40.653600000"	54.45689	-4.8069
1	317	359°59'57.651000000	Z95°03'43.431840000"	54.44899	-4.8229
1	318	0°00'13.906080000"	Z95°03'16.021440000"	54.45357	-4.81602
1	319	0°00'26.464320000"	Z95°03'40.395960000"	54.45265	-4.82242
1	320	0°00'29.428920000"	Z95°03'50.887080000"	54.45328	-4.82527
1	321	0°00'32.173200000"	Z95°03'47.647080000"	54.45163	-4.82426
1	322	0°00'35.578440000"	Z95°03'46.655640000"	54.4548	-4.82428
1	323	0°00'30.822120000"	Z95°03'49.655880000"	54.45264	-4.82488
1	324	0°00'31.463640000"	Z95°03'43.334640000"	54.45118	-4.82307
1	325	0°00'27.540000000"	Z95°03'46.493640000"	54.44979	-4.82379
1	326	0°00'29.218320000"	Z95°03'45.878040000"	54.45263	-4.82388
1	327	0°00'37.182240000"	Z95°03'46.960200000"	54.45202	-4.82411
1	328	0°00'30.248640000"	Z95°03'45.058320000"	54.45305	-4.8237
1	329	0°00'32.792040000"	Z95°03'46.289520000"	54.44878	-4.82365
1	330	0°00'34.473600000"	Z95°03'49.037040000"	54.45758	-4.82516
1	331	0°00'29.548800000"	Z95°03'48.794040000"	54.45326	-4.82471
1	332	0°00'28.317600000"	Z95°03'48.217320000"	54.45227	-4.82447
1	333	0°00'32.873040000"	Z95°03'43.373520000"	54.45264	-4.82321
1	334	0°00'31.353480000"	Z95°03'49.199040000"	54.45205	-4.82471
1	335	0°00'28.081080000"	Z95°03'50.349240000"	54.45073	-4.8249
1	336	0°00'29.957040000"	Z95°03'49.325400000"	54.45257	-4.82479
1	337	0°00'30.002400000"	Z95°03'48.463560000"	54.44974	-4.82431
1	338	0°00'29.137320000"	Z95°03'51.852600000"	54.45247	-4.82545
1	339	0°00'29.837160000"	Z95°03'45.178200000"	54.4374	-4.82234
1	340	0°01'24.314520000"	Z95°03'43.146720000"	54.45193	-4.82309
1	341	0°00'28.709640000"	Z95°03'30.870360000"	54.4525	-4.81987
1	342	0°00'24.630480000"	Z95°03'48.878280000"	54.4514	-4.82457
1	343	0°00'32.915160000"	Z95°03'49.749840000"	54.45177	-4.82483
1	344	0°00'26.402760000"	Z95°03'49.040280000"	54.45231	-4.82469
1	345	0°00'04.383720000"	Z95°03'41.040720000"	54.44941	-4.8223
1	346	0°00'25.229880000"	Z95°03'43.593840000"	54.45247	-4.82326
1	347	0°00'35.108640000"	Z95°03'51.502680000"	54.45244	-4.82536
1	348	0°00'39.845520000"	Z95°03'44.468640000"	54.45251	-4.82349
1	349	0°00'19.760760000"	Z95°03'47.572560000"	54.45174	-4.82425
1	350	0°00'39.609000000"	Z95°03'43.985880000"	54.45228	-4.82334

1	351	0°00'25.634880000"	Z95°03'50.725080000"	54.45278	-4.82518
1	352	0°00'28.975320000"	Z95°03'40.211280000"	54.45237	-4.82235
1	353	0°00'06.680880000"	Z95°03'44.300160000"	54.4522	-4.82342
1	354	0°00'28.077840000"	Z95°03'46.681560000"	54.4527	-4.8241
1	355	0°00'30.132000000"	Z95°03'42.608880000"	54.45241	-4.82299
1	356	0°00'29.150280000"	Z95°03'42.171480000"	54.45208	-4.82284
1	357	0°00'29.535840000"	Z95°03'45.035640000"	54.45217	-4.82361
1	358	359°59'42.367920000	Z95°03'40.311720000"	54.45113	-4.82226
1	359	0°00'31.434480000"	Z95°03'44.753760000"	54.45275	-4.82359
1	380	0°00'26.833680000"	Z95°03'42.346440000"	54.45287	-4.82296
1	381	0°00'25.712640000"	Z95°03'38.983320000"	54.4524	-4.82202
1	382	0°00'27.413640000"	Z95°03'38.520000000"	54.45292	-4.82195
1	383	0°00'25.596000000"	Z95°03'39.874320000"	54.45316	-4.82233
1	384	0°00'26.487000000"	Z95°03'43.888680000"	54.45286	-4.82337
1	385	0°00'26.098200000"	Z95°03'41.494320000"	54.45259	-4.82271
1	386	0°00'26.020440000"	Z95°03'42.537600000"	54.45268	-4.82299
1	387	0°00'25.171560000"	Z95°03'47.287440000"	54.45132	-4.82414
1	388	0°00'28.531440000"	Z95°03'39.294360000"	54.45252	-4.82212
1	389	0°00'29.189160000"	Z95°03'41.727600000"	54.45352	-4.82285
1	390	0°00'26.833680000"	Z95°03'45.858600000"	54.45249	-4.82386
1	391	0°00'29.574720000"	Z95°03'42.074280000"	54.45255	-4.82286
1	392	0°00'31.544640000"	Z95°03'42.615360000"	54.45246	-4.82299
1	393	0°00'25.751520000"	Z95°03'44.005320000"	54.45147	-4.82328
1	394	0°00'27.258120000"	Z95°03'46.399680000"	54.45293	-4.82404
1	395	0°00'31.042440000"	Z95°03'41.572080000"	54.45172	-4.82265
1	396	0°00'23.820480000"	Z95°03'40.298760000"	54.4528	-4.82241
1	397	0°00'25.482600000"	Z95°03'38.983320000"	54.45088	-4.82189
1	398	0°00'27.954720000"	Z95°03'40.645440000"	54.44722	-4.82201
1	399	0°00'28.764720000"	Z95°03'40.992120000"	54.4534	-4.82265

EXPERIMENT 4

From Point ID	To Point ID	H. Angle	V. Angle	H. Distance	V. Distance
1	400	0°00'24.018120000"	Z90°40'50.081520000"	39.13766	-0.46481
1	401	0°00'24.993360000"	Z90°40'48.169920000"	39.13873	-0.46446
1	402	0°00'21.024360000"	Z90°40'49.958400000"	39.13822	-0.46479
1	403	0°00'28.149120000"	Z90°40'46.893360000"	39.13791	-0.46421
1	404	0°00'12.823920000"	Z90°40'51.384000000"	39.13864	-0.46507
1	405	0°00'21.092400000"	Z90°40'50.930400000"	39.1384	-0.46498
1	406	0°00'20.250000000"	Z90°40'45.001200000"	39.13916	-0.46386
1	407	0°00'27.614520000"	Z90°40'51.837600000"	39.13642	-0.46513
1	408	0°00'26.976240000"	Z90°40'49.835280000"	39.13765	-0.46476
1	409	0°00'23.211360000"	Z90°40'50.781360000"	39.13873	-0.46495
1	410	0°00'24.692040000"	Z90°40'53.039640000"	39.13782	-0.46537
1	411	0°00'23.201640000"	Z90°40'52.190760000"	39.13807	-0.46521
1	412	0°00'33.909840000"	Z90°40'50.923920000"	39.13888	-0.46498
1	413	0°00'30.669840000"	Z90°40'56.250480000"	39.1383	-0.46599
1	414	0°00'27.329400000"	Z90°40'45.127560000"	39.13787	-0.46387
1	415	0°00'13.805640000"	Z90°41'01.227120000"	39.13812	-0.46693
1	416	0°00'21.458520000"	Z90°40'53.869080000"	39.13842	-0.46554
1	417	0°00'22.965120000"	Z90°40'50.162520000"	39.13889	-0.46484
1	418	0°00'26.989200000"	Z90°40'52.132440000"	39.1379	-0.4652
1	419	0°00'14.612400000"	Z90°41'01.609440000"	39.13868	-0.46701
1	420	0°00'25.686720000"	Z90°40'53.120640000"	39.13895	-0.4654
1	421	0°00'26.234280000"	Z90°40'55.009560000"	39.13929	-0.46576
1	422	0°00'20.888280000"	Z90°40'54.069960000"	39.13833	-0.46557
1	423	0°00'21.743640000"	Z90°40'54.682320000"	39.13807	-0.46569
1	424	0°00'27.209520000"	Z90°40'49.209960000"	39.13864	-0.46465
1	425	0°00'29.506680000"	Z90°40'55.009560000"	39.13934	-0.46576
1	426	0°00'28.560600000"	Z90°40'51.853800000"	39.13876	-0.46516
1	427	0°00'26.632800000"	Z90°40'55.135920000"	39.13881	-0.46578
1	428	0°00'20.761920000"	Z90°40'54.889680000"	39.13881	-0.46573
1	429	0°00'29.260440000"	Z90°40'54.397200000"	39.13961	-0.46565
1	430	0°00'24.948000000"	Z90°40'57.737640000"	39.13857	-0.46627
1	431	0°00'23.269680000"	Z90°40'51.934800000"	39.13813	-0.46517
1	432	0°00'26.998920000"	Z90°40'49.245600000"	39.13819	-0.46466
1	433	0°00'22.521240000"	Z90°40'49.018800000"	39.13847	-0.46462
1	434	0°00'25.932960000"	Z90°40'53.451120000"	39.13743	-0.46544
1	435	0°00'24.747120000"	Z90°40'51.141000000"	39.13875	-0.46502
1	436	0°00'25.340040000"	Z90°40'51.769560000"	39.14051	-0.46516
1	437	0°00'21.134520000"	Z90°40'50.331000000"	39.13958	-0.46488
1	438	0°00'24.977160000"	Z90°40'52.181040000"	39.13835	-0.46521
1	439	0°00'25.401600000"	Z90°40'55.709400000"	39.13808	-0.46588
1	440	0°00'27.695520000"	Z90°40'50.745720000"	39.13891	-0.46495
1	441	0°00'28.939680000"	Z90°40'49.514520000"	39.13856	-0.46471
1	442	0°00'25.913520000"	Z90°40'50.350440000"	39.1382	-0.46487
1	443	0°00'22.877640000"	Z90°40'53.814000000"	39.13846	-0.46553
1	444	0°00'24.481440000"	Z90°40'50.667960000"	39.13894	-0.46493
1	445	0°00'22.945680000"	Z90°40'50.761920000"	39.13832	-0.46495
1	446	0°00'19.433520000"	Z90°40'51.698280000"	39.13872	-0.46513
1	447	0°00'29.655720000"	Z90°40'47.761680000"	39.1383	-0.46438
1	448	0°00'31.635360000"	Z90°40'46.880400000"	39.13873	-0.46421
1	449	0°00'33.420600000"	Z90°40'49.086840000"	39.13823	-0.46463
1	450	0°00'28.294920000"	Z90°40'50.350440000"	39.13821	-0.46487

1	451	0°00'31.658040000"	Z90°40'50.172240000"	39.13889	-0.46484
1	452	0°00'38.060280000"	Z90°40'47.541360000"	39.13883	-0.46434
1	453	0°00'19.047960000"	Z90°40'52.310640000"	39.13883	-0.46525
1	454	0°00'35.733960000"	Z90°40'45.707520000"	39.13884	-0.46399
1	455	0°00'29.195640000"	Z90°40'50.953080000"	39.13884	-0.46499
1	456	0°00'24.121800000"	Z90°40'51.128040000"	39.13851	-0.46502
1	457	0°00'28.868400000"	Z90°40'47.998200000"	39.13824	-0.46442
1	458	0°00'19.624680000"	Z90°40'50.528640000"	39.13855	-0.4649
1	459	0°00'24.708240000"	Z90°40'46.711920000"	39.13869	-0.46418
1	460	0°00'25.272000000"	Z90°40'46.792920000"	39.13897	-0.4642
1	461	0°00'23.988960000"	Z90°40'48.396720000"	39.13896	-0.4645
1	462	0°00'29.166480000"	Z90°40'52.080600000"	39.13871	-0.4652
1	463	0°00'31.505760000"	Z90°40'48.273600000"	39.13894	-0.46448
1	464	0°00'36.100080000"	Z90°40'48.468000000"	39.13875	-0.46451
1	465	0°00'28.278720000"	Z90°40'50.431440000"	39.13896	-0.46489
1	466	0°00'27.578880000"	Z90°40'43.157640000"	39.13919	-0.46351
1	467	0°00'23.321520000"	Z90°40'50.457360000"	39.1387	-0.46489
1	468	0°00'26.010720000"	Z90°40'49.757520000"	39.13911	-0.46476
1	469	0°00'34.049160000"	Z90°40'50.998440000"	39.13925	-0.465
1	470	0°00'28.939680000"	Z90°40'46.938720000"	39.13899	-0.46423
1	471	0°00'29.273400000"	Z90°40'49.647360000"	39.13911	-0.46474
1	472	0°00'30.115800000"	Z90°40'48.617040000"	39.13883	-0.46454
1	473	0°00'27.222480000"	Z90°40'50.476800000"	39.13932	-0.4649
1	474	0°00'33.083640000"	Z90°40'50.833200000"	39.13912	-0.46497
1	475	0°00'31.645080000"	Z90°40'45.866280000"	39.13927	-0.46403
1	476	0°00'33.495120000"	Z90°40'51.863520000"	39.13936	-0.46517
1	477	0°00'21.895920000"	Z90°40'43.954680000"	39.13908	-0.46366
1	478	0°00'19.825560000"	Z90°40'47.868600000"	39.13942	-0.46441
1	479	0°00'29.338200000"	Z90°40'49.375200000"	39.13905	-0.46469
1	480	0°00'25.323840000"	Z90°40'51.160440000"	39.1393	-0.46503
1	481	0°00'25.903800000"	Z90°40'50.813760000"	39.13888	-0.46496
1	482	0°00'27.604800000"	Z90°40'48.574920000"	39.13863	-0.46453
1	483	0°00'26.678160000"	Z90°40'52.320360000"	39.13912	-0.46525
1	484	0°00'28.029240000"	Z90°40'50.120400000"	39.13898	-0.46483
1	485	0°00'27.063720000"	Z90°40'50.350440000"	39.1389	-0.46487
1	486	0°00'30.579120000"	Z90°40'50.194920000"	39.13896	-0.46485
1	487	0°00'29.380320000"	Z90°40'50.428200000"	39.13924	-0.46489
1	488	0°00'28.531440000"	Z90°40'50.194920000"	39.13915	-0.46485
1	489	0°00'32.549040000"	Z90°40'53.324760000"	39.13899	-0.46544
1	490	0°00'29.341440000"	Z90°40'51.199320000"	39.13892	-0.46504
1	491	0°00'31.116960000"	Z90°40'48.999360000"	39.1389	-0.46462
1	492	0°00'28.107000000"	Z90°40'44.016240000"	39.13906	-0.46367
1	493	0°00'30.190320000"	Z90°40'48.574920000"	39.13877	-0.46454
1	494	0°00'26.289360000"	Z90°40'47.107200000"	39.13891	-0.46426
1	495	0°00'29.535840000"	Z90°40'48.727200000"	39.13886	-0.46457
1	496	0°00'26.600400000"	Z90°40'48.302760000"	39.13933	-0.46449
1	497	0°00'27.912600000"	Z90°40'46.757280000"	39.13913	-0.46419
1	498	0°00'31.042440000"	Z90°40'53.865840000"	39.13904	-0.46554
1	499	0°00'24.358320000"	Z90°40'49.190520000"	39.13906	-0.46466

EXPERIMENT 5

From Point ID	To Point ID	H. Angle	V. Angle	H. Distance	V. Distance
1	500	0°00'30.721680000"	Z99°53'23.021880000"	151.5564	-26.4212
1	501	0°00'27.854280000"	Z99°53'23.213040000"	151.55656	-26.42138
1	502	0°00'37.506240000"	Z99°53'27.548160000"	151.55541	-26.42446
1	503	0°00'32.098680000"	Z99°53'23.676360000"	151.55636	-26.42169
1	504	0°00'29.885760000"	Z99°53'23.358840000"	151.55586	-26.42136
1	505	0°00'33.271560000"	Z99°53'23.705520000"	151.55558	-26.42158
1	506	0°00'30.851280000"	Z99°53'22.927920000"	151.55644	-26.42114
1	507	0°00'32.817960000"	Z99°53'24.385920000"	151.55684	-26.42231
1	508	0°00'31.586760000"	Z99°53'23.566200000"	151.55613	-26.42157
1	509	0°00'30.225960000"	Z99°53'23.436600000"	151.55563	-26.42138
1	510	0°00'30.582360000"	Z99°53'23.653680000"	151.55525	-26.42148
1	511	0°00'30.585600000"	Z99°53'23.763840000"	151.55567	-26.42164
1	512	0°00'44.128800000"	Z99°53'17.510640000"	151.55718	-26.41717
1	513	0°00'28.836000000"	Z99°53'23.802720000"	151.55591	-26.42171
1	514	0°00'29.872800000"	Z99°53'24.314640000"	151.55532	-26.42199
1	515	0°00'29.364120000"	Z99°53'24.129960000"	151.55516	-26.42182
1	516	0°00'30.277800000"	Z99°53'23.656920000"	151.55521	-26.42148
1	517	0°00'30.585600000"	Z99°53'24.415080000"	151.55548	-26.4221
1	518	0°00'26.898480000"	Z99°53'25.967040000"	151.55576	-26.42332
1	519	0°00'29.940840000"	Z99°53'23.802720000"	151.55649	-26.42181
1	520	0°00'29.629800000"	Z99°53'15.864720000"	151.55957	-26.41634
1	521	0°00'27.300240000"	Z99°53'14.426160000"	151.55959	-26.41525
1	522	0°00'28.641600000"	Z99°53'14.510400000"	151.55909	-26.41523
1	523	0°00'29.422440000"	Z99°53'16.276200000"	151.55843	-26.41645
1	524	0°00'28.482840000"	Z99°53'14.798760000"	151.55888	-26.41541
1	525	0°00'27.990360000"	Z99°53'14.017920000"	151.5581	-26.41468
1	526	0°00'30.653640000"	Z99°53'16.642320000"	151.55758	-26.41658
1	527	0°00'30.818880000"	Z99°53'16.807560000"	151.55775	-26.41673
1	528	0°00'28.317600000"	Z99°53'18.573360000"	151.55604	-26.41777
1	529	0°00'27.452520000"	Z99°53'16.149840000"	151.55755	-26.4162
1	530	0°00'30.206520000"	Z99°53'19.678200000"	151.55604	-26.41861
1	531	0°00'30.206520000"	Z99°53'19.678200000"	151.55673	-26.41873
1	532	0°00'29.176200000"	Z99°53'16.561320000"	151.557	-26.41642
1	533	0°00'29.383560000"	Z99°53'18.939480000"	151.55749	-26.4183
1	534	0°00'27.290520000"	Z99°53'17.546280000"	151.55733	-26.41722
1	535	0°00'27.290520000"	Z99°53'17.546280000"	151.5578	-26.4173
1	536	0°00'27.290520000"	Z99°53'17.134800000"	151.55783	-26.41699
1	537	0°00'28.810080000"	Z99°53'18.858480000"	151.55845	-26.41841
1	538	0°00'29.960280000"	Z99°53'20.627520000"	151.55741	-26.41957
1	539	0°00'28.071360000"	Z99°53'17.627280000"	151.55771	-26.41735
1	540	0°00'35.568720000"	Z99°53'18.809880000"	151.55796	-26.41829
1	541	0°00'35.928360000"	Z99°53'19.678200000"	151.55811	-26.41897
1	542	0°00'36.216720000"	Z99°53'18.421080000"	151.55833	-26.41806
1	543	0°00'35.030880000"	Z99°53'18.978360000"	151.55846	-26.4185
1	544	0°00'35.299800000"	Z99°53'18.333600000"	151.55826	-26.41798
1	545	0°00'34.953120000"	Z99°53'17.549520000"	151.55813	-26.41736
1	546	0°00'46.306080000"	Z99°53'20.216040000"	151.55778	-26.41932
1	547	0°00'36.414360000"	Z99°53'17.290320000"	151.55802	-26.41715
1	548	0°00'34.855920000"	Z99°53'18.553920000"	151.55825	-26.41814
1	549	0°00'35.840880000"	Z99°53'16.933920000"	151.55837	-26.41694
1	550	0°00'34.914240000"	Z99°53'18.165120000"	151.55823	-26.41785

1	551	0°00'35.063280000"	Z99°53'16.739520000"	151.55831	-26.41678
1	552	0°00'34.305120000"	Z99°53'17.834640000"	151.55824	-26.4176
1	553	0°00'35.034120000"	Z99°53'16.982520000"	151.55812	-26.41693
1	554	0°00'35.034120000"	Z99°53'16.490040000"	151.55878	-26.41667
1	555	0°00'35.474760000"	Z99°53'18.638160000"	151.55809	-26.41818
1	556	0°00'35.782560000"	Z99°53'17.358360000"	151.55839	-26.41726
1	557	0°00'34.936920000"	Z99°53'18.631680000"	151.5582	-26.41819
1	558	0°00'34.097760000"	Z99°53'19.535640000"	151.55834	-26.4189
1	559	0°00'34.473600000"	Z99°53'19.461120000"	151.55802	-26.41879
1	560	0°00'34.638840000"	Z99°53'20.258160000"	151.55786	-26.41936
1	561	0°00'35.299800000"	Z99°53'19.665240000"	151.55804	-26.41895
1	562	0°00'35.163720000"	Z99°53'18.907080000"	151.55814	-26.41839
1	563	0°00'34.146360000"	Z99°53'19.085280000"	151.5582	-26.41853
1	564	0°00'34.603200000"	Z99°53'18.712680000"	151.5579	-26.4182
1	565	0°00'34.749000000"	Z99°53'18.553920000"	151.55808	-26.41811
1	566	0°00'35.040600000"	Z99°53'18.294720000"	151.55812	-26.41792
1	567	0°00'35.189640000"	Z99°53'19.279680000"	151.55806	-26.41866
1	568	0°00'34.473600000"	Z99°53'18.800160000"	151.55803	-26.41829
1	569	0°00'34.690680000"	Z99°53'18.226680000"	151.55836	-26.41791
1	570	0°00'34.755480000"	Z99°53'18.579840000"	151.55779	-26.41808
1	571	0°00'36.203760000"	Z99°53'16.671480000"	151.55849	-26.41676
1	572	0°00'34.632360000"	Z99°53'15.910080000"	151.55838	-26.41616
1	573	0°00'34.395840000"	Z99°53'17.682360000"	151.55867	-26.41756
1	574	0°00'35.970480000"	Z99°53'18.119760000"	151.55844	-26.41785
1	575	0°00'34.878600000"	Z99°53'18.434040000"	151.55789	-26.41799
1	576	0°00'34.292160000"	Z99°53'17.782800000"	151.55754	-26.41744
1	577	0°00'35.238240000"	Z99°53'18.362760000"	151.55837	-26.41802
1	578	0°00'38.675880000"	Z99°53'16.515960000"	151.55824	-26.4166
1	579	0°00'35.831160000"	Z99°53'16.081800000"	151.55835	-26.41629
1	580	0°00'29.804760000"	Z99°53'10.739040000"	151.55993	-26.41252
1	581	0°00'30.038040000"	Z99°53'15.874440000"	151.55853	-26.41616
1	582	0°00'28.531440000"	Z99°53'18.540960000"	151.55845	-26.41817
1	583	0°00'30.692520000"	Z99°53'15.372240000"	151.55852	-26.41578
1	584	0°00'31.311360000"	Z99°53'15.722160000"	151.55857	-26.41605
1	585	0°00'30.268080000"	Z99°53'17.497680000"	151.55823	-26.41734
1	586	0°00'29.419200000"	Z99°53'18.229920000"	151.55799	-26.41785
1	587	0°00'33.051240000"	Z99°53'19.273200000"	151.55794	-26.41863
1	588	0°00'31.969080000"	Z99°53'19.545360000"	151.55779	-26.41881
1	589	0°00'34.324560000"	Z99°53'18.771000000"	151.55763	-26.4182
1	590	0°00'31.735800000"	Z99°53'16.493280000"	151.55816	-26.41657
1	591	0°00'29.150280000"	Z99°53'16.493280000"	151.55805	-26.41655
1	592	0°00'29.150280000"	Z99°53'16.493280000"	151.55901	-26.41671
1	593	0°00'29.613600000"	Z99°53'17.614320000"	151.55832	-26.41744
1	594	0°00'29.613600000"	Z99°53'17.614320000"	151.55844	-26.41746
1	595	0°00'32.046840000"	Z99°53'18.809880000"	151.55806	-26.4183
1	596	0°00'29.185920000"	Z99°53'17.151000000"	151.55774	-26.41699
1	597	0°00'29.688120000"	Z99°53'16.995480000"	151.55838	-26.41699
1	598	0°00'29.613600000"	Z99°53'19.120920000"	151.55814	-26.41855
1	599	0°00'29.613600000"	Z99°53'19.120920000"	151.55784	-26.4185

EXPERIMENT 6

From Point ID	To Point ID	H. Angle	V. Angle	H. Distance	V. Distance
1	600	0°00'30.579120000"	Z94°38'06.903960000"	293.32786	-23.77636
1	601	0°00'30.890160000"	Z94°38'06.084240000"	293.32802	-23.7752
1	602	0°00'30.799440000"	Z94°38'07.111320000"	293.32807	-23.77668
1	603	0°00'34.392600000"	Z94°38'09.615840000"	293.32795	-23.78025
1	604	0°00'26.619840000"	Z94°38'07.101600000"	293.32883	-23.77672
1	605	0°00'30.268080000"	Z94°38'08.148120000"	293.32795	-23.77815
1	606	0°00'24.024600000"	Z94°38'11.300640000"	293.32843	-23.7827
1	607	0°00'22.216680000"	Z94°38'10.723920000"	293.32861	-23.78189
1	608	0°00'30.494880000"	Z94°38'06.690120000"	293.32838	-23.7761
1	609	0°00'24.423120000"	Z94°38'09.670920000"	293.3301	-23.7805
1	610	359°59'51.819000000	Z94°38'13.118280000"	293.3288	-23.78533
1	611	0°00'32.101920000"	Z94°38'09.162240000"	293.3291	-23.77969
1	612	0°00'31.308120000"	Z94°38'07.937520000"	293.32992	-23.77801
1	613	0°00'38.345400000"	Z94°38'14.028720000"	293.32958	-23.7867
1	614	0°00'30.465720000"	Z94°38'07.853280000"	293.32945	-23.77785
1	615	0°00'41.096160000"	Z94°38'06.489240000"	293.33041	-23.77598
1	616	0°00'31.146120000"	Z94°38'07.597320000"	293.32999	-23.77753
1	617	0°00'30.993840000"	Z94°38'08.015280000"	293.32906	-23.77805
1	618	0°00'31.113720000"	Z94°38'07.020600000"	293.32995	-23.7767
1	619	0°00'31.136400000"	Z94°38'06.738720000"	293.32945	-23.77625
1	620	0°00'29.422440000"	Z94°38'07.671840000"	293.33065	-23.77769
1	621	0°00'30.780000000"	Z94°38'07.415880000"	293.33049	-23.77731
1	622	0°00'31.311360000"	Z94°38'07.574640000"	293.33123	-23.7776
1	623	0°00'29.960280000"	Z94°38'06.916920000"	293.33164	-23.77669
1	624	0°00'29.302560000"	Z94°38'07.049760000"	293.33098	-23.77682
1	625	0°00'31.764960000"	Z94°38'07.701000000"	293.33163	-23.77781
1	626	0°00'28.408320000"	Z94°38'06.797040000"	293.33088	-23.77645
1	627	0°00'28.191240000"	Z94°38'06.797040000"	293.33143	-23.7765
1	628	0°00'28.767960000"	Z94°38'06.797040000"	293.33151	-23.77651
1	629	0°00'29.260440000"	Z94°38'08.640600000"	293.33034	-23.77905
1	630	0°00'30.096360000"	Z94°38'06.589680000"	293.33091	-23.77616
1	631	0°00'31.026240000"	Z94°38'07.901880000"	293.33133	-23.77807
1	632	0°00'30.572640000"	Z94°38'08.109240000"	293.3304	-23.77829
1	633	0°00'31.146120000"	Z94°38'07.001160000"	293.33098	-23.77675
1	634	0°00'31.146120000"	Z94°38'07.001160000"	293.33081	-23.77674
1	635	0°00'31.845960000"	Z94°38'07.124280000"	293.33067	-23.7769
1	636	0°00'31.272480000"	Z94°38'08.355480000"	293.32999	-23.77861
1	637	0°00'31.230360000"	Z94°38'06.243000000"	293.33079	-23.77565
1	638	0°00'29.383560000"	Z94°38'06.304560000"	293.33039	-23.77571
1	639	0°00'30.258360000"	Z94°38'07.289520000"	293.32997	-23.77709
1	640	0°00'34.716600000"	Z94°38'08.540160000"	293.33027	-23.7789
1	641	0°00'37.179000000"	Z94°38'07.010880000"	293.33059	-23.77674
1	642	0°00'34.622640000"	Z94°38'07.869480000"	293.3305	-23.77796
1	643	0°00'34.888320000"	Z94°38'06.463320000"	293.3311	-23.77599
1	644	0°00'33.971400000"	Z94°38'06.936360000"	293.33058	-23.77663
1	645	0°00'34.888320000"	Z94°38'06.826200000"	293.33072	-23.77648
1	646	0°00'34.324560000"	Z94°38'06.343440000"	293.33073	-23.77579
1	647	0°00'34.846200000"	Z94°38'06.194400000"	293.33117	-23.77561
1	648	0°00'34.217640000"	Z94°38'07.250640000"	293.33093	-23.77711
1	649	0°00'35.267400000"	Z94°38'05.420040000"	293.33058	-23.77446
1	650	0°00'37.017000000"	Z94°38'05.271000000"	293.33095	-23.77428

1	651	0°00'34.992000000"	Z94°38'07.150200000"	293.33061	-23.77694
1	652	0°00'34.936920000"	Z94°38'06.984960000"	293.33028	-23.77667
1	653	0°00'34.830000000"	Z94°38'06.907200000"	293.33063	-23.77659
1	654	0°00'35.513640000"	Z94°38'07.386720000"	293.32966	-23.7772
1	655	0°00'35.646480000"	Z94°38'07.399680000"	293.33083	-23.77731
1	656	0°00'34.502760000"	Z94°38'09.405240000"	293.33025	-23.78014
1	657	0°00'34.421760000"	Z94°38'05.624160000"	293.32998	-23.7747
1	658	0°00'35.170200000"	Z94°38'07.448280000"	293.33054	-23.77736
1	659	0°00'28.239840000"	Z94°38'06.570240000"	293.33021	-23.77608
1	660	0°00'34.784640000"	Z94°38'04.639200000"	293.33119	-23.77339
1	661	0°00'34.784640000"	Z94°38'04.882200000"	293.33101	-23.77372
1	662	0°00'33.977880000"	Z94°38'06.835920000"	293.33082	-23.7765
1	663	0°00'34.661520000"	Z94°38'05.465400000"	293.33122	-23.77457
1	664	0°00'34.599960000"	Z94°38'06.236520000"	293.33129	-23.77568
1	665	0°00'34.797600000"	Z94°38'05.779680000"	293.33097	-23.775
1	666	0°00'34.237080000"	Z94°38'06.324000000"	293.33022	-23.77572
1	667	0°00'34.739280000"	Z94°38'06.285120000"	293.33098	-23.77573
1	668	0°00'34.538400000"	Z94°38'05.296920000"	293.3313	-23.77434
1	669	0°00'34.817040000"	Z94°38'05.676000000"	293.33137	-23.77489
1	670	0°00'34.888320000"	Z94°38'05.267760000"	293.33125	-23.77429
1	671	0°00'34.564320000"	Z94°38'04.856280000"	293.3311	-23.77369
1	672	0°00'34.156080000"	Z94°38'05.031240000"	293.3312	-23.77395
1	673	0°00'34.593480000"	Z94°38'06.324000000"	293.3305	-23.77575
1	674	0°00'33.151680000"	Z94°38'05.562600000"	293.33081	-23.77468
1	675	0°00'33.634440000"	Z94°38'04.645680000"	293.33099	-23.77338
1	676	0°00'33.744600000"	Z94°38'04.616520000"	293.33108	-23.77335
1	677	0°00'33.637680000"	Z94°38'03.770880000"	293.33149	-23.77217
1	678	0°00'31.959360000"	Z94°38'04.315200000"	293.33156	-23.77296
1	679	0°00'33.696000000"	Z94°38'02.465160000"	293.33108	-23.77027
1	680	0°00'30.268080000"	Z94°38'01.140000000"	293.33184	-23.76843
1	681	0°00'28.298160000"	Z94°38'01.719960000"	293.3317	-23.76925
1	682	0°00'30.540240000"	Z94°38'00.906720000"	293.33177	-23.76809
1	683	0°00'30.423600000"	Z94°38'00.057840000"	293.33149	-23.76686
1	684	0°00'31.350240000"	Z94°38'01.755600000"	293.33144	-23.76928
1	685	0°00'30.384720000"	Z94°38'00.790080000"	293.33126	-23.76789
1	686	0°00'30.540240000"	Z94°37'59.980080000"	293.3313	-23.76673
1	687	0°00'30.731400000"	Z94°38'01.370040000"	293.33127	-23.76872
1	688	0°00'29.804760000"	Z94°37'57.469080000"	293.33132	-23.76314
1	689	0°00'31.622400000"	Z94°38'00.676680000"	293.33125	-23.76772
1	690	0°00'30.384720000"	Z94°38'00.521160000"	293.33143	-23.76751
1	691	0°00'30.540240000"	Z94°37'59.208960000"	293.3319	-23.76567
1	692	0°00'31.120200000"	Z94°37'59.053440000"	293.33163	-23.76543
1	693	0°00'29.302560000"	Z94°37'58.667880000"	293.33162	-23.76488
1	694	0°00'29.574720000"	Z94°37'58.590120000"	293.33177	-23.76478
1	695	0°00'30.731400000"	Z94°37'59.170080000"	293.33143	-23.76558
1	696	0°00'30.154680000"	Z94°37'58.165680000"	293.33184	-23.76418
1	697	0°00'30.423600000"	Z94°37'58.317960000"	293.33142	-23.76436
1	698	0°00'31.735800000"	Z94°37'56.697960000"	293.33177	-23.76207
1	699	0°00'29.688120000"	Z94°37'59.014560000"	293.33193	-23.7654

EXPERIMENT 7

From Point ID	To Point ID	H. Angle	V. Angle	H. Distance	V. Distance
1	700	0°00'29.995920000"	Z94°38'03.476040000"	293.33123	-23.77173
1	701	0°00'29.607120000"	Z94°38'03.514920000"	293.3313	-23.77179
1	702	0°00'29.691360000"	Z94°38'02.760000000"	293.3309	-23.77068
1	703	0°00'29.445120000"	Z94°38'03.084000000"	293.33216	-23.77124
1	704	0°00'18.111600000"	Z94°38'02.708160000"	293.33112	-23.77062
1	705	0°00'32.144040000"	Z94°38'02.021280000"	293.33037	-23.76958
1	706	0°00'29.163240000"	Z94°38'02.542920000"	293.33137	-23.7704
1	707	0°00'29.409480000"	Z94°38'03.696360000"	293.33134	-23.77205
1	708	0°00'36.177840000"	Z94°37'58.865520000"	293.3315	-23.76515
1	709	0°00'31.405320000"	Z94°38'01.548240000"	293.33155	-23.76899
1	710	0°00'30.533760000"	Z94°38'01.703760000"	293.33177	-23.76924
1	711	0°00'29.911680000"	Z94°38'02.108760000"	293.33126	-23.76977
1	712	0°00'29.882520000"	Z94°38'01.635720000"	293.33136	-23.7691
1	713	0°00'30.060720000"	Z94°38'01.940280000"	293.33097	-23.76951
1	714	0°00'31.752000000"	Z94°38'02.837760000"	293.33061	-23.77076
1	715	0°00'29.769120000"	Z94°38'02.730840000"	293.33098	-23.77064
1	716	0°00'32.451840000"	Z94°38'01.804200000"	293.33136	-23.76935
1	717	0°00'26.441640000"	Z94°38'00.504960000"	293.33167	-23.76751
1	718	0°00'34.084800000"	Z94°38'01.745880000"	293.33131	-23.76926
1	719	0°00'30.258360000"	Z94°38'02.018040000"	293.33041	-23.76957
1	720	0°00'31.149360000"	Z94°38'00.790080000"	293.33052	-23.76783
1	721	0°00'30.533760000"	Z94°38'01.221000000"	293.33144	-23.76852
1	722	0°00'29.833920000"	Z94°37'59.503800000"	293.33146	-23.76606
1	723	0°00'27.332640000"	Z94°37'59.941200000"	293.33085	-23.76664
1	724	0°00'30.245400000"	Z94°38'00.981240000"	293.33113	-23.76815
1	725	0°00'29.626560000"	Z94°38'02.568840000"	293.33008	-23.77034
1	726	0°00'31.395600000"	Z94°38'01.907880000"	293.3309	-23.76946
1	727	0°00'30.818880000"	Z94°37'57.851400000"	293.33141	-23.76369
1	728	0°00'30.533760000"	Z94°38'01.872240000"	293.32993	-23.76933
1	729	0°00'29.752920000"	Z94°38'01.130280000"	293.33063	-23.76832
1	730	0°00'29.633040000"	Z94°38'02.364720000"	293.33113	-23.77013
1	731	0°00'29.633040000"	Z94°38'02.364720000"	293.33124	-23.77014
1	732	0°00'30.491640000"	Z94°38'01.745880000"	293.33097	-23.76923
1	733	0°00'29.043360000"	Z94°38'00.479040000"	293.33227	-23.76752
1	734	0°00'31.356720000"	Z94°37'58.836360000"	293.33192	-23.76514
1	735	0°00'30.945240000"	Z94°38'02.403600000"	293.33086	-23.77016
1	736	0°00'30.984120000"	Z94°38'01.499640000"	293.3307	-23.76886
1	737	0°00'30.984120000"	Z94°38'01.499640000"	293.33082	-23.76887
1	738	0°00'30.864240000"	Z94°38'00.232800000"	293.33118	-23.76708
1	739	0°00'30.656880000"	Z94°38'00.099960000"	293.33093	-23.76687
1	740	0°00'33.064200000"	Z94°37'58.965960000"	293.33286	-23.7654
1	741	0°00'33.666840000"	Z94°37'57.605160000"	293.33226	-23.76341
1	742	0°00'32.999400000"	Z94°37'59.772720000"	293.33219	-23.76651
1	743	0°00'33.349320000"	Z94°37'59.607480000"	293.33215	-23.76627
1	744	0°00'33.329880000"	Z94°37'58.953000000"	293.33217	-23.76533
1	745	0°00'37.571040000"	Z94°38'02.069880000"	293.33228	-23.7698
1	746	0°00'33.067440000"	Z94°37'59.989800000"	293.33213	-23.76681
1	747	0°00'32.856840000"	Z94°37'59.921760000"	293.33204	-23.76671
1	748	0°00'32.701320000"	Z94°37'59.377440000"	293.33182	-23.76591
1	749	0°00'33.138720000"	Z94°37'59.662560000"	293.33158	-23.7663
1	750	0°00'37.221120000"	Z94°37'59.319120000"	293.33252	-23.76588

1	751	0°00'32.798520000"	Z94°38'00.015720000"	293.33231	-23.76686
1	752	0°00'32.387040000"	Z94°38'00.459600000"	293.33176	-23.76745
1	753	0°00'32.937840000"	Z94°37'59.675520000"	293.33219	-23.76637
1	754	0°00'33.216480000"	Z94°37'59.704680000"	293.33188	-23.76638
1	755	0°00'32.801760000"	Z94°37'59.617200000"	293.33231	-23.76629
1	756	0°00'32.830920000"	Z94°38'00.488760000"	293.33181	-23.7675
1	757	0°00'32.069520000"	Z94°38'04.094880000"	293.33169	-23.77265
1	758	0°00'32.574960000"	Z94°38'00.168000000"	293.3317	-23.76703
1	759	0°00'32.902200000"	Z94°38'00.119400000"	293.33248	-23.76702
1	760	0°00'32.753160000"	Z94°37'59.711160000"	293.3326	-23.76645
1	761	0°00'32.950800000"	Z94°37'59.821320000"	293.33271	-23.76662
1	762	0°00'32.950800000"	Z94°37'59.429280000"	293.3325	-23.76604
1	763	0°00'32.860080000"	Z94°37'59.513520000"	293.33201	-23.76612
1	764	0°00'32.892480000"	Z94°37'59.390400000"	293.33255	-23.76599
1	765	0°00'32.649480000"	Z94°37'59.730600000"	293.33269	-23.76648
1	766	0°00'32.967000000"	Z94°37'59.341800000"	293.33268	-23.76593
1	767	0°00'32.928120000"	Z94°37'59.594520000"	293.33289	-23.76631
1	768	0°00'32.474520000"	Z94°37'59.341800000"	293.33264	-23.76592
1	769	0°00'32.788800000"	Z94°37'59.536200000"	293.33191	-23.76614
1	770	0°00'32.762880000"	Z94°37'59.328840000"	293.33282	-23.76592
1	771	0°00'32.769360000"	Z94°37'59.484360000"	293.33259	-23.76612
1	772	0°00'32.493960000"	Z94°37'59.549160000"	293.33236	-23.7662
1	773	0°00'32.724000000"	Z94°37'59.115000000"	293.33271	-23.76561
1	774	0°00'32.613840000"	Z94°37'58.593360000"	293.3326	-23.76485
1	775	0°00'32.879520000"	Z94°37'58.943280000"	293.33263	-23.76535
1	776	0°00'32.801760000"	Z94°37'59.257560000"	293.33236	-23.76578
1	777	0°00'32.691600000"	Z94°37'58.982160000"	293.33257	-23.7654
1	778	0°00'32.672160000"	Z94°37'59.594520000"	293.33244	-23.76627
1	779	0°00'32.837400000"	Z94°37'59.545920000"	293.33315	-23.76626
1	780	0°00'28.881360000"	Z94°37'56.928000000"	293.33296	-23.7625
1	781	0°00'28.456920000"	Z94°37'57.780120000"	293.33235	-23.76367
1	782	0°00'28.998000000"	Z94°37'58.010160000"	293.3329	-23.76404
1	783	0°00'28.842480000"	Z94°37'56.195760000"	293.33322	-23.76147
1	784	0°00'28.690200000"	Z94°37'56.386920000"	293.33278	-23.76171
1	785	0°00'28.729080000"	Z94°37'56.351280000"	293.33322	-23.76169
1	786	0°00'27.646920000"	Z94°37'57.005760000"	293.33306	-23.76261
1	787	0°00'27.763560000"	Z94°37'56.079120000"	293.33317	-23.7613
1	788	0°00'28.651320000"	Z94°37'56.659080000"	293.33256	-23.76208
1	789	0°00'29.231280000"	Z94°37'57.277920000"	293.33292	-23.76299
1	790	0°00'27.685800000"	Z94°37'56.001360000"	293.3327	-23.76115
1	791	0°00'28.379160000"	Z94°37'56.386920000"	293.33296	-23.76172
1	792	0°00'29.305800000"	Z94°37'56.040240000"	293.33295	-23.76122
1	793	0°00'28.188000000"	Z94°37'55.810200000"	293.33317	-23.76091
1	794	0°00'27.724680000"	Z94°37'56.814600000"	293.33311	-23.76235
1	795	0°00'28.612440000"	Z94°37'56.620200000"	293.33259	-23.76202
1	796	0°00'28.612440000"	Z94°37'56.620200000"	293.33267	-23.76203
1	797	0°00'27.222480000"	Z94°37'57.430200000"	293.33292	-23.76321
1	798	0°00'28.495800000"	Z94°37'57.585720000"	293.33302	-23.76344
1	799	0°00'28.573560000"	Z94°37'56.736840000"	293.3328	-23.76221

EXPERIMENT 8

From Point ID	To Point ID	H. Angle	V. Angle	H. Distance	V. Distance
1	800	0°00'29.415960000"	Z99°06'15.260040000"	164.49369	-26.3582
1	801	0°00'27.854280000"	Z99°06'14.715720000"	164.49325	-26.35768
1	802	0°00'26.354160000"	Z99°06'11.981160000"	164.49357	-26.3555
1	803	0°00'25.715880000"	Z99°06'11.310480000"	164.49339	-26.35492
1	804	0°00'29.480760000"	Z99°06'16.536600000"	164.49429	-26.35934
1	805	0°00'27.426600000"	Z99°06'12.207960000"	164.49374	-26.35571
1	806	0°00'26.736480000"	Z99°06'17.414640000"	164.49217	-26.35972
1	807	0°00'28.217160000"	Z99°06'17.084160000"	164.49297	-26.35958
1	808	0°00'24.176880000"	Z99°06'17.968680000"	164.49155	-26.36007
1	809	0°00'24.180120000"	Z99°06'08.608320000"	164.49407	-26.35282
1	810	0°00'29.623320000"	Z99°06'13.740480000"	164.49344	-26.35692
1	811	0°00'25.032240000"	Z99°06'13.202640000"	164.49399	-26.35656
1	812	0°00'26.120880000"	Z99°06'12.493080000"	164.49358	-26.35592
1	813	0°00'30.540240000"	Z99°06'15.843240000"	164.49273	-26.35852
1	814	0°00'28.009800000"	Z99°06'17.897400000"	164.49375	-26.36037
1	815	0°00'26.052840000"	Z99°06'11.378520000"	164.49331	-26.35496
1	816	0°00'30.938760000"	Z99°06'12.943440000"	164.49376	-26.35632
1	817	0°00'28.848960000"	Z99°06'10.711080000"	164.49344	-26.35444
1	818	0°00'27.407160000"	Z99°06'11.310480000"	164.49423	-26.35506
1	819	0°00'26.856360000"	Z99°06'12.493080000"	164.4941	-26.356
1	820	0°00'26.263440000"	Z99°06'13.860360000"	164.49366	-26.35705
1	821	0°00'29.464560000"	Z99°06'22.679640000"	164.49189	-26.36398
1	822	0°00'30.303720000"	Z99°06'17.634960000"	164.49378	-26.36016
1	823	0°00'27.740880000"	Z99°06'17.758080000"	164.49363	-26.36023
1	824	0°00'28.440720000"	Z99°06'18.746280000"	164.49393	-26.36109
1	825	0°00'28.725840000"	Z99°06'16.607880000"	164.49421	-26.35938
1	826	0°00'28.933200000"	Z99°06'11.316960000"	164.49508	-26.3552
1	827	0°00'27.209520000"	Z99°06'14.375520000"	164.49425	-26.35756
1	828	0°00'27.948240000"	Z99°06'16.964280000"	164.4939	-26.35963
1	829	0°00'27.864000000"	Z99°06'15.337800000"	164.49418	-26.35834
1	830	0°00'27.702000000"	Z99°06'15.840000000"	164.49474	-26.35884
1	831	0°00'28.110240000"	Z99°06'16.290360000"	164.49451	-26.35917
1	832	0°00'28.356480000"	Z99°06'13.043880000"	164.49562	-26.3567
1	833	0°00'31.311360000"	Z99°06'13.759920000"	164.49552	-26.35727
1	834	0°00'28.806840000"	Z99°06'14.718960000"	164.49517	-26.35799
1	835	0°00'26.836920000"	Z99°06'19.316520000"	164.49295	-26.3614
1	836	0°00'27.290520000"	Z99°06'16.601400000"	164.49457	-26.35944
1	837	0°00'27.987120000"	Z99°06'13.374360000"	164.49485	-26.35684
1	838	0°00'27.783000000"	Z99°06'15.506280000"	164.49357	-26.35838
1	839	0°00'27.083160000"	Z99°06'15.010560000"	164.49438	-26.35811
1	840	0°00'29.927880000"	Z99°06'15.399360000"	164.49397	-26.35836
1	841	0°00'34.463880000"	Z99°06'13.503960000"	164.49407	-26.35682
1	842	0°00'35.076240000"	Z99°06'12.020040000"	164.49431	-26.35565
1	843	0°00'30.290760000"	Z99°06'13.163760000"	164.49399	-26.35653
1	844	0°00'31.379400000"	Z99°06'15.324840000"	164.49365	-26.35825
1	845	0°00'34.120440000"	Z99°06'11.456280000"	164.49469	-26.35525
1	846	0°00'35.714520000"	Z99°06'15.956640000"	164.49404	-26.35883
1	847	0°00'33.517800000"	Z99°06'12.726360000"	164.49368	-26.35612
1	848	0°00'35.215560000"	Z99°06'09.891360000"	164.49433	-26.35391
1	849	0°00'32.296320000"	Z99°06'09.100800000"	164.49427	-26.35325
1	850	0°00'31.470120000"	Z99°06'09.330840000"	164.49453	-26.35348

1	851	0°00'36.576360000"	Z99°06'13.410000000"	164.49388	-26.35672
1	852	0°00'33.174360000"	Z99°06'11.741400000"	164.49418	-26.3554
1	853	0°00'32.873040000"	Z99°06'14.787000000"	164.49389	-26.35784
1	854	0°00'31.590000000"	Z99°06'10.934640000"	164.49415	-26.35474
1	855	0°00'31.690440000"	Z99°06'12.862440000"	164.49485	-26.35642
1	856	0°00'31.382640000"	Z99°06'12.946680000"	164.494	-26.35636
1	857	0°00'30.721680000"	Z99°06'15.561360000"	164.49338	-26.3584
1	858	0°00'31.204440000"	Z99°06'12.629160000"	164.49448	-26.35617
1	859	0°00'33.527520000"	Z99°06'13.280400000"	164.49388	-26.35661
1	860	0°00'32.788800000"	Z99°06'09.505800000"	164.49498	-26.3537
1	861	0°00'32.387040000"	Z99°06'09.042480000"	164.49518	-26.35335
1	862	0°00'32.325480000"	Z99°06'08.916120000"	164.49527	-26.35326
1	863	0°00'32.691600000"	Z99°06'09.978840000"	164.49459	-26.35402
1	864	0°00'32.652720000"	Z99°06'10.137600000"	164.49494	-26.35421
1	865	0°00'31.531680000"	Z99°06'10.147320000"	164.49475	-26.35419
1	866	0°00'31.962600000"	Z99°06'13.053600000"	164.4946	-26.35654
1	867	0°00'32.889240000"	Z99°06'12.528720000"	164.49424	-26.35605
1	868	0°00'32.604120000"	Z99°06'12.567600000"	164.49454	-26.35613
1	869	0°00'33.323400000"	Z99°06'14.618520000"	164.49396	-26.35772
1	870	0°00'32.212080000"	Z99°06'11.423880000"	164.49439	-26.35517
1	871	0°00'32.344920000"	Z99°06'11.158200000"	164.49461	-26.35499
1	872	0°00'32.270400000"	Z99°06'13.179960000"	164.49456	-26.35664
1	873	0°00'31.275720000"	Z99°06'08.987400000"	164.49467	-26.35323
1	874	0°00'31.904280000"	Z99°06'12.463920000"	164.49485	-26.3561
1	875	0°00'32.344920000"	Z99°06'14.343120000"	164.49432	-26.35755
1	876	0°00'32.289840000"	Z99°06'13.743720000"	164.49451	-26.35709
1	877	0°00'34.878600000"	Z99°06'13.108680000"	164.49434	-26.35654
1	878	0°00'32.711040000"	Z99°06'13.228560000"	164.49476	-26.35671
1	879	0°00'32.769360000"	Z99°06'12.823560000"	164.49423	-26.35629
1	880	0°00'30.504600000"	Z99°06'07.299360000"	164.49533	-26.35195
1	881	0°00'30.621240000"	Z99°06'15.023520000"	164.49372	-26.35801
1	882	0°00'29.461320000"	Z99°06'12.126960000"	164.49487	-26.35583
1	883	0°00'30.656880000"	Z99°06'12.784680000"	164.49427	-26.35627
1	884	0°00'30.812400000"	Z99°06'11.200320000"	164.49471	-26.35504
1	885	0°00'30.773520000"	Z99°06'08.767080000"	164.49505	-26.35311
1	886	0°00'30.157920000"	Z99°06'08.650440000"	164.49528	-26.35305
1	887	0°00'31.275720000"	Z99°06'10.118160000"	164.49493	-26.35419
1	888	0°00'31.275720000"	Z99°06'10.040400000"	164.49472	-26.35409
1	889	0°00'30.967920000"	Z99°06'13.672440000"	164.49418	-26.35698
1	890	0°00'29.383560000"	Z99°06'11.430360000"	164.49529	-26.35532
1	891	0°00'30.271320000"	Z99°06'08.031600000"	164.49522	-26.35253
1	892	0°00'29.924640000"	Z99°06'09.499320000"	164.49477	-26.35366
1	893	0°00'29.189160000"	Z99°06'05.562720000"	164.49483	-26.35045
1	894	0°00'29.189160000"	Z99°06'05.562720000"	164.49554	-26.35056
1	895	0°00'29.228040000"	Z99°06'11.702520000"	164.49494	-26.35549
1	896	0°00'30.387960000"	Z99°06'12.512520000"	164.4942	-26.35603
1	897	0°00'29.655720000"	Z99°06'13.248000000"	164.49418	-26.35663
1	898	0°00'29.655720000"	Z99°06'13.248000000"	164.4942	-26.35664
1	899	0°00'28.418040000"	Z99°06'05.792760000"	164.49549	-26.35074

EXPERIMENT 9

From Point ID	To Point ID	H. Angle	V. Angle	H. Distance	V. Distance
1	900	0°00'29.160000000"	Z97°25'13.485720000"	99.33312	-12.93642
1	901	0°00'35.591400000"	Z97°25'17.811120000"	99.33296	-12.93852
1	902	0°00'28.709640000"	Z97°25'12.957600000"	99.33317	-12.93617
1	903	0°00'28.900800000"	Z97°25'09.908760000"	99.33323	-12.93468
1	904	0°00'28.680480000"	Z97°25'11.418600000"	99.33269	-12.93535
1	905	0°00'25.327080000"	Z97°25'10.560000000"	99.33339	-12.93503
1	906	0°00'27.128520000"	Z97°25'13.469520000"	99.33368	-12.93649
1	907	0°00'22.129200000"	Z97°25'14.412360000"	99.33313	-12.93688
1	908	0°00'46.121400000"	Z97°25'19.949520000"	99.33363	-12.93965
1	909	0°00'21.798720000"	Z97°25'15.267720000"	99.33345	-12.93734
1	910	0°00'25.110000000"	Z97°25'10.906680000"	99.33355	-12.93522
1	911	0°00'12.879000000"	Z97°25'17.817600000"	99.33271	-12.93849
1	912	0°00'26.234280000"	Z97°25'13.476000000"	99.33332	-12.93644
1	913	0°00'20.402280000"	Z97°25'10.994160000"	99.33284	-12.93517
1	914	0°00'44.705520000"	Z97°25'14.473920000"	99.33473	-12.93712
1	915	0°00'27.232200000"	Z97°25'10.825680000"	99.33329	-12.93514
1	916	0°00'21.912120000"	Z97°25'15.053880000"	99.33347	-12.93724
1	917	0°00'30.154680000"	Z97°25'09.153840000"	99.33381	-12.93439
1	918	0°00'30.096360000"	Z97°25'12.591480000"	99.3339	-12.93609
1	919	0°00'23.723280000"	Z97°25'15.488040000"	99.3329	-12.93737
1	920	0°00'30.371760000"	Z97°25'14.179080000"	99.33344	-12.9368
1	921	0°00'27.948240000"	Z97°25'08.677560000"	99.33369	-12.93414
1	922	0°00'28.933200000"	Z97°25'16.686840000"	99.33221	-12.93787
1	923	0°00'29.260440000"	Z97°25'17.545440000"	99.33267	-12.93835
1	924	0°00'29.467800000"	Z97°25'13.644480000"	99.33229	-12.93639
1	925	0°00'26.924400000"	Z97°25'12.086040000"	99.33271	-12.93568
1	926	0°00'29.879280000"	Z97°25'09.937920000"	99.33272	-12.93463
1	927	0°00'28.440720000"	Z97°25'12.286920000"	99.33315	-12.93584
1	928	0°00'28.933200000"	Z97°25'10.362360000"	99.3331	-12.93489
1	929	0°00'28.194480000"	Z97°25'15.779640000"	99.33201	-12.9374
1	930	0°00'29.506680000"	Z97°25'11.172360000"	99.33253	-12.93521
1	931	0°00'26.059320000"	Z97°25'10.728480000"	99.33241	-12.93498
1	932	0°00'27.251640000"	Z97°25'10.628040000"	99.3325	-12.93494
1	933	0°00'30.329640000"	Z97°25'12.876600000"	99.33316	-12.93613
1	934	0°00'30.491640000"	Z97°25'15.079800000"	99.33187	-12.93704
1	935	0°00'26.717040000"	Z97°25'14.671560000"	99.3323	-12.9369
1	936	0°00'28.605960000"	Z97°25'10.621560000"	99.33246	-12.93493
1	937	0°00'27.455760000"	Z97°25'11.577360000"	99.33267	-12.93543
1	938	0°00'29.014200000"	Z97°25'17.435280000"	99.33145	-12.93814
1	939	0°00'29.260440000"	Z97°25'12.977040000"	99.33155	-12.93597
1	940	0°00'31.249800000"	Z97°25'06.331800000"	99.33492	-12.93315
1	941	0°00'36.900360000"	Z97°25'06.335040000"	99.33449	-12.9331
1	942	0°00'34.301880000"	Z97°25'04.643760000"	99.33436	-12.93225
1	943	0°00'33.346080000"	Z97°25'09.221880000"	99.33409	-12.93446
1	944	0°00'33.103080000"	Z97°25'08.512320000"	99.33422	-12.93413
1	945	0°00'27.841320000"	Z97°25'12.747000000"	99.33367	-12.93613
1	946	0°00'32.526360000"	Z97°25'07.164480000"	99.33382	-12.93342
1	947	0°00'32.302800000"	Z97°25'03.969840000"	99.33407	-12.93189
1	948	0°00'35.001720000"	Z97°25'05.534760000"	99.33363	-12.93259
1	949	0°00'31.389120000"	Z97°25'10.423920000"	99.33415	-12.93506
1	950	0°00'32.351400000"	Z97°25'08.016600000"	99.33388	-12.93384

1	951	0°00'31.930200000"	Z97°25'10.090200000"	99.33366	-12.93483
1	952	0°00'29.202120000"	Z97°25'08.612760000"	99.33359	-12.9341
1	953	0°00'31.683960000"	Z97°25'12.105480000"	99.33396	-12.93586
1	954	0°00'32.639760000"	Z97°25'08.266080000"	99.33411	-12.934
1	955	0°00'31.580280000"	Z97°25'08.421600000"	99.33476	-12.93416
1	956	0°00'32.886000000"	Z97°25'08.952960000"	99.33444	-12.93437
1	957	0°00'35.490960000"	Z97°25'09.001560000"	99.33414	-12.93436
1	958	0°00'34.334280000"	Z97°25'06.130920000"	99.33388	-12.93292
1	959	0°00'30.980880000"	Z97°25'03.911520000"	99.33392	-12.93184
1	960	0°00'32.675400000"	Z97°25'06.147120000"	99.3343	-12.93298
1	961	0°00'33.060960000"	Z97°25'06.827520000"	99.33415	-12.9333
1	962	0°00'33.090120000"	Z97°25'15.556080000"	99.33426	-12.93758
1	963	0°00'34.515720000"	Z97°25'10.381800000"	99.33425	-12.93505
1	964	0°00'34.301880000"	Z97°25'07.316760000"	99.33471	-12.93361
1	965	0°00'32.312520000"	Z97°25'08.207760000"	99.33432	-12.93399
1	966	0°00'31.664520000"	Z97°25'07.488480000"	99.33451	-12.93367
1	967	0°00'34.204680000"	Z97°25'08.450760000"	99.33448	-12.93413
1	968	0°00'32.785560000"	Z97°25'07.731480000"	99.33426	-12.93375
1	969	0°00'32.970240000"	Z97°25'07.977720000"	99.33415	-12.93386
1	970	0°00'33.848280000"	Z97°25'05.486160000"	99.33446	-12.93268
1	971	0°00'34.418520000"	Z97°25'11.152920000"	99.33429	-12.93543
1	972	0°00'33.806160000"	Z97°25'05.687040000"	99.3344	-12.93277
1	973	0°00'34.016760000"	Z97°25'05.081160000"	99.33451	-12.93249
1	974	0°00'33.482160000"	Z97°25'06.396600000"	99.33445	-12.93312
1	975	0°00'32.960520000"	Z97°25'08.518800000"	99.3346	-12.93418
1	976	0°00'32.707800000"	Z97°25'08.590080000"	99.33455	-12.93421
1	977	0°00'32.558760000"	Z97°25'06.176280000"	99.33405	-12.93296
1	978	0°00'33.521040000"	Z97°25'09.014520000"	99.33412	-12.93436
1	979	0°00'33.294240000"	Z97°25'09.782400000"	99.33414	-12.93474
1	980	0°00'31.081320000"	Z97°25'03.785160000"	99.33468	-12.93187
1	981	0°00'31.930200000"	Z97°25'04.672920000"	99.33486	-12.93233
1	982	0°00'31.389120000"	Z97°25'05.136240000"	99.33457	-12.93252
1	983	0°00'31.852440000"	Z97°25'07.958280000"	99.33404	-12.93384
1	984	0°00'29.574720000"	Z97°25'07.919400000"	99.33424	-12.93384
1	985	0°00'29.574720000"	Z97°25'07.919400000"	99.33443	-12.93387
1	986	0°00'30.812400000"	Z97°25'04.789560000"	99.33436	-12.93233
1	987	0°00'28.029240000"	Z97°25'04.135080000"	99.33483	-12.93207
1	988	0°00'28.340280000"	Z97°25'10.660440000"	99.33401	-12.93515
1	989	0°00'32.241240000"	Z97°25'07.339440000"	99.33448	-12.93359
1	990	0°00'30.851280000"	Z97°25'08.304960000"	99.33416	-12.93402
1	991	0°00'32.241240000"	Z97°25'05.175120000"	99.33484	-12.93258
1	992	0°00'30.618000000"	Z97°25'12.591480000"	99.33411	-12.93611
1	993	0°00'31.197960000"	Z97°25'09.153840000"	99.33436	-12.93446
1	994	0°00'32.856840000"	Z97°25'07.533840000"	99.33435	-12.93367
1	995	0°00'32.280120000"	Z97°25'09.928200000"	99.33387	-12.93478
1	996	0°00'30.812400000"	Z97°25'12.167040000"	99.33448	-12.93595
1	997	0°00'30.964680000"	Z97°25'11.240400000"	99.33434	-12.93548
1	998	0°00'26.522640000"	Z97°25'11.820360000"	99.3341	-12.93573
1	999	0°00'29.960280000"	Z97°25'11.084880000"	99.33404	-12.93537

EXPERIMENT 10

From Point ID	To Point ID	H. Angle	V. Angle	H. Distance	V. Distance
1	1000	0°00'28.362960000"	Z99°02'04.817760000"	153.18498	-24.3555
1	1001	0°00'28.751760000"	Z99°02'05.128800000"	153.18515	-24.35576
1	1002	0°00'31.353480000"	Z99°02'03.907320000"	153.18424	-24.35469
1	1003	0°00'30.232440000"	Z99°02'05.643960000"	153.18389	-24.35596
1	1004	0°00'28.589760000"	Z99°02'03.466680000"	153.18436	-24.35437
1	1005	0°00'30.964680000"	Z99°02'02.815440000"	153.18524	-24.35402
1	1006	0°00'09.243720000"	Z99°02'01.406040000"	153.18673	-24.35318
1	1007	0°00'28.204200000"	Z99°02'03.226920000"	153.18415	-24.35416
1	1008	0°00'32.555520000"	Z99°02'10.215600000"	153.18501	-24.35962
1	1009	0°00'36.543960000"	Z99°02'08.964960000"	153.18292	-24.35833
1	1010	0°00'29.633040000"	Z99°02'07.613880000"	153.18364	-24.35742
1	1011	0°00'28.874880000"	Z99°02'02.637240000"	153.18476	-24.3538
1	1012	0°00'31.865400000"	Z99°02'05.731440000"	153.18401	-24.35604
1	1013	0°00'32.892480000"	Z99°02'06.502560000"	153.18239	-24.35637
1	1014	0°00'28.220400000"	Z99°02'03.965640000"	153.18322	-24.35457
1	1015	0°00'26.457840000"	Z99°02'02.867280000"	153.18485	-24.35399
1	1016	0°00'29.603880000"	Z99°02'03.285240000"	153.18469	-24.35429
1	1017	0°00'26.707320000"	Z99°02'05.553240000"	153.18427	-24.35595
1	1018	0°00'38.769840000"	Z99°01'59.666160000"	153.18322	-24.3513
1	1019	0°00'38.753640000"	Z99°02'03.359760000"	153.18581	-24.35452
1	1020	0°00'30.864240000"	Z99°02'04.668720000"	153.18379	-24.3552
1	1021	0°00'28.894320000"	Z99°02'05.015400000"	153.18562	-24.35575
1	1022	0°00'30.575880000"	Z99°01'58.976040000"	153.18748	-24.35145
1	1023	0°00'30.209760000"	Z99°02'01.561560000"	153.18677	-24.3533
1	1024	0°00'28.567080000"	Z99°02'01.927680000"	153.18649	-24.35354
1	1025	0°00'29.717280000"	Z99°01'58.493280000"	153.18695	-24.351
1	1026	0°00'28.239840000"	Z99°02'01.882320000"	153.18724	-24.35362
1	1027	0°00'27.948240000"	Z99°02'00.858480000"	153.18686	-24.35278
1	1028	0°00'27.663120000"	Z99°02'02.753880000"	153.18594	-24.35408
1	1029	0°00'28.605960000"	Z99°02'02.838120000"	153.18629	-24.3542
1	1030	0°00'28.605960000"	Z99°02'03.366240000"	153.1859	-24.35454
1	1031	0°00'28.605960000"	Z99°02'01.555080000"	153.18603	-24.35318
1	1032	0°00'27.828360000"	Z99°01'59.792520000"	153.18712	-24.35201
1	1033	0°00'29.837160000"	Z99°02'00.349800000"	153.18715	-24.35244
1	1034	0°00'29.879280000"	Z99°02'04.649280000"	153.18614	-24.35556
1	1035	0°00'29.552040000"	Z99°01'59.377800000"	153.18676	-24.35164
1	1036	0°00'28.813320000"	Z99°02'06.606240000"	153.18514	-24.35689
1	1037	0°00'30.456000000"	Z99°01'59.695320000"	153.18713	-24.35194
1	1038	0°00'30.371760000"	Z99°02'03.466680000"	153.1853	-24.35452
1	1039	0°00'30.371760000"	Z99°02'03.405120000"	153.18567	-24.35453
1	1040	0°00'34.898040000"	Z99°01'57.417600000"	153.18703	-24.35019
1	1041	0°00'35.785800000"	Z99°01'56.254440000"	153.18676	-24.34926
1	1042	0°00'34.483320000"	Z99°01'54.242400000"	153.18699	-24.34777
1	1043	0°00'35.510400000"	Z99°01'55.178760000"	153.18772	-24.3486
1	1044	0°00'34.457400000"	Z99°01'58.127160000"	153.18628	-24.35061
1	1045	0°00'36.145440000"	Z99°02'01.888800000"	153.18621	-24.35347
1	1046	0°00'29.480760000"	Z99°02'06.816840000"	153.18539	-24.35709
1	1047	0°00'30.643920000"	Z99°01'58.917720000"	153.187	-24.35133
1	1048	0°00'34.574040000"	Z99°01'58.117440000"	153.18629	-24.35061
1	1049	0°00'34.165800000"	Z99°02'00.074400000"	153.18633	-24.3521
1	1050	0°00'54.143640000"	Z99°02'12.298920000"	153.18228	-24.36077

1	1051	0°00'35.358120000"	Z99°01'57.119520000"	153.18707	-24.34997
1	1052	0°00'35.873280000"	Z99°01'53.873040000"	153.1871	-24.3475
1	1053	0°00'35.870040000"	Z99°01'56.656200000"	153.18607	-24.34946
1	1054	0°00'35.743680000"	Z99°01'56.371080000"	153.18648	-24.34931
1	1055	0°00'36.955440000"	Z99°01'56.756640000"	153.18618	-24.34955
1	1056	0°00'36.437040000"	Z99°01'54.621480000"	153.18732	-24.34811
1	1057	0°00'35.231760000"	Z99°01'54.553440000"	153.187	-24.34801
1	1058	0°00'32.296320000"	Z99°01'56.559000000"	153.18666	-24.34948
1	1059	0°00'35.290080000"	Z99°01'57.991080000"	153.1866	-24.35056
1	1060	0°00'37.085040000"	Z99°02'01.840200000"	153.18671	-24.35351
1	1061	0°00'35.776080000"	Z99°01'56.335440000"	153.18761	-24.34946
1	1062	0°00'36.673560000"	Z99°01'58.046160000"	153.18729	-24.35071
1	1063	0°00'35.361360000"	Z99°01'54.796440000"	153.18756	-24.34828
1	1064	0°00'36.634680000"	Z99°01'59.721240000"	153.18678	-24.3519
1	1065	0°00'36.663840000"	Z99°02'01.201920000"	153.18647	-24.35298
1	1066	0°00'36.731880000"	Z99°01'59.173680000"	153.18683	-24.3515
1	1067	0°00'35.970480000"	Z99°01'59.743920000"	153.18704	-24.35196
1	1068	0°00'36.443520000"	Z99°02'01.182480000"	153.18729	-24.3531
1	1069	0°00'35.785800000"	Z99°01'59.961000000"	153.18674	-24.35208
1	1070	0°00'36.207000000"	Z99°01'57.803160000"	153.18697	-24.35048
1	1071	0°00'35.737200000"	Z99°01'59.620800000"	153.18665	-24.35181
1	1072	0°00'36.190800000"	Z99°02'00.528000000"	153.1867	-24.35251
1	1073	0°00'35.737200000"	Z99°01'56.863560000"	153.18707	-24.34978
1	1074	0°00'36.236160000"	Z99°01'56.636760000"	153.18668	-24.34954
1	1075	0°00'36.644400000"	Z99°02'01.778640000"	153.18638	-24.35341
1	1076	0°00'36.446760000"	Z99°01'59.358360000"	153.18701	-24.35166
1	1077	0°00'35.964000000"	Z99°01'58.431720000"	153.18742	-24.35103
1	1078	0°00'35.529840000"	Z99°01'56.047080000"	153.18709	-24.34916
1	1079	0°00'35.607600000"	Z99°01'56.785800000"	153.18698	-24.3497
1	1080	0°00'33.210000000"	Z99°01'53.694840000"	153.18745	-24.34742
1	1081	0°00'32.280120000"	Z99°01'59.063520000"	153.18701	-24.35144
1	1082	0°00'33.825600000"	Z99°01'56.552520000"	153.18717	-24.34955
1	1083	0°00'31.972320000"	Z99°01'54.080400000"	153.18753	-24.34773
1	1084	0°00'31.933440000"	Z99°01'59.873520000"	153.1869	-24.35204
1	1085	0°00'31.933440000"	Z99°01'59.873520000"	153.18647	-24.35197
1	1086	0°00'33.362280000"	Z99°02'00.570120000"	153.18667	-24.35253
1	1087	0°00'31.933440000"	Z99°01'56.166960000"	153.18725	-24.34927
1	1088	0°00'33.210000000"	Z99°02'00.492360000"	153.18691	-24.35251
1	1089	0°00'31.625640000"	Z99°01'56.513640000"	153.18717	-24.34953
1	1090	0°00'32.474520000"	Z99°01'55.240320000"	153.18721	-24.34856
1	1091	0°00'32.011200000"	Z99°01'56.361360000"	153.18714	-24.3494
1	1092	0°00'32.357880000"	Z99°01'57.790200000"	153.18669	-24.35042
1	1093	0°00'32.743440000"	Z99°01'59.219040000"	153.18663	-24.3515
1	1094	0°00'30.812400000"	Z99°01'55.781400000"	153.18721	-24.34897
1	1095	0°00'34.020000000"	Z99°01'56.439120000"	153.18699	-24.34944
1	1096	0°00'31.972320000"	Z99°01'56.591400000"	153.1873	-24.34961
1	1097	0°00'30.349080000"	Z99°01'54.235920000"	153.18729	-24.34781
1	1098	0°00'32.937840000"	Z99°01'59.063520000"	153.18698	-24.35144
1	1099	0°00'32.166720000"	Z99°01'59.024640000"	153.18647	-24.35133