Experiences With An Active Target Total Station For Precise Angle Measurement

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<u>Abstract</u>:

This paper details the process and procedures used to measure precise horizontal angles using a Geodimeter 640 servo-driven total station with Autolock/RMT targeting and a Husky FS/2 hand-held computer used in the Fermi Main Injector tunnel traverse. The system has shown to have comparable accuracy to that of the Kern E2, while significantly increasing productivity.

<u>Background</u>:

The development of this system began in December, 1995, while looking for a better way to center over a traverse point. As is certainly obvious, the closer an instrument is to the mark, height-wise, the less lateral displacement effect is induced due to the resolution of leveling bubbles and optical plummets. Simple enough: put the instrument closer to the floor. But what of observer comfort? How long can a human being withstand lying prone, head raised to peer through a telescope? What effect will this have on the precision of the quantity being observed and how rapidly will the observer's *precision coefficient* deteriorate? The short answers are: increasingly large and bloody quick.

Setting aside the issue of centering for the moment, at least for the prone position, the idea of robotic angle measurement flashed forth. Could a servo-driven total station provide angular precision equal to that of a Kern E2? Recalling a statement, really an off-hand remark, by an old compatriot from the early days of total station development, that the automatic aiming system they had recently created had, what seemed to be, incredible accuracy. *Incredible* and *Accuracy* must always be taken in context. With the accuracy specification for the distance measuring engine of this instrument being ±(2 mm + 2 ppm), is it possible that the angular accuracy of this system is capable of achieving satisfactory results? Several telephone calls and e-mail messages produced details that were encouraging enough to proceed.

The System:

Since we had in inventory the basic total station required for a test, a Geodimeter 640, we made contact with the Geotronics (now known as Spectra Precision) office in Itasca, IL, through their local dealer. When we described what we wanted to do, they offered to install an Autolock system for a month, on a trial basis. The Geodimeter 640 had been (and still is) a construction work-horse, being used daily for control and stake-out for Fermilab's new Main Injector project.

Geodimeter 640

The Autolock system is comprised of two principal parts, plus some additional software in the total station. The target, known as RMT, is 70x130x20mm block with a 40mm retro-reflecting prism mounted 60mm above a small infrared emitter diode. There is a small bulls-eye on top of the block and a thumb-screw port for two AA cell batteries, along with an auxiliary battery connector. The diode emits a sine wave modulated signal. Mounting is via the traditional 5/8”-11 hole, available top and bottom.

Autolock tracker RMT

The second part of the system is the tracker, which mounts under the telescope body of the total station. It is approximately 60mm high, 65mm wide, and 130mm deep, approximating the size of the small battery module it replaces. The active component is a quadrature detector diode which analyzes the signal from the RMT. Output from the detector drives the servos until zero-crossing is achieved.

The tracker has its own collimation procedure which can be performed in a matter of minutes. The process is entirely automatic.

The questions to be answered were:

- is the point of emission in the plane of the mounting hole, ie. can signal phase be detected
- is the signal from the RMT’s emitter ‘stationary’ with time
- is the resolution of the detector sufficiently fine in order to be useful
- is the instruments horizontal circle up to the task
- can it be made to be productive
- will it compare equivalently to the Kern E2

There was initial concern as to whether the Geodimeter's circles had sufficient resolution for this task. The so-called 'electronic micrometer', which, in the case of the Geodimeter, scans the entire circle electromagnetically, has a least count 0.1cc (0.03"). The instrument displays the angles with a resolution of 1.0cc (0.32") for both horizontal and vertical circles, which, in terms of total stations, is as good as it gets. The accuracy, stated as the standard deviation of a direction, measured direct and reverse, per DIN Spec. No. 18723, is 3.0cc (0.97").

Development:

Initial testing consisted of manually operating the data collection on the Geodimeter 640, over six setups of the Main Injector's secondary control traverse. This is a Kern E2 - Mekometer traverse, which runs down the center of the tunnel. Courses vary from 50-100 meters in length, with an angle generally between 190-200g. Normal operation of this instrument is in the STD mode, which collects data over a period of about 3.5 seconds. There is also D-bar mode, where data is collected by continuous rerunning of the STD mode. In the D-bar mode, an additional digit of resolution is displayed, which allows the operator to view the running average of the observations. When the values on the display cease to change, the observer registers the data. The data in this process was collected using the D-bar mode.

For this test, two RMTs, backsight and foresight, set on tooling stands which had been centered over the traverse points using a Wild NL nadir plummet. The Geodimeter 640 was also mounted on a tooling stand and centered by using the Wild NL. While the standard precise traverse observing program for the Kern, as used at Fermilab, is eight sets of direct and reverse observations, the Autolock system required a slight modification to this protocol for its program. At this time the Autolock system does not allow observations with the telescope inverted, however, this is not truly an issue since the instrument uses dual-axis compensation and electronic level sensors, and it applies collimation, vertical index, and trunnion axis corrections automatically. However, it was necessary to devise an alternative program that represented an equal, or greater, protocol, in terms of observation density, to that of the E2. It was decided to observe the traverse station angles sixteen times.

In the manual collection method, this meant pointing the instrument toward the backsight, letting the Autolock do the 'finish' pointing by allowing the instrument to sample using the D-bar mode, register the data, then repeat the process for the foresight, repeating this sixteen times. The hardest part of this program seemed to be that the observer loses count - usually sixteen sets, but sometimes fifteen sets, other times nineteen sets.

Our initial objective was to establish a rejection criteria such that 75% of the observations were kept from any set. From the first six setups, we established a preliminary rejection limit of 3.5cc (1.13”) for horizontal angles. After observing twenty setups, it became apparent that a rejection limit of 2.5cc (0.8”) was attainable. Interestingly, while the objective was to use only the horizontal angle from this procedure, the zenith distance rejection limit also conforms to the 2.5cc figure, and the distance measurements at 0.35mm. What has been determined over the past 18 months of this investigation is that if an angle fails to conform to the rejection limit, an environmental explanation is highly likely. What with doors being opened, air drying equipment and/or heaters being operated, or the ubiquitous golf carts violating beneficial occupancy, changes in the horizontal and vertical refractivity can be shown to be the primary culprit. Typically, 14-16 sets pass the test when conditions are good, but when there is a problem, all three observational components seem to be effected. The zenith distance observation seems to be the most sensitive, which, when normal air density models are considered, is to be expected. Experience may ultimately dictate that when extreme precision is required, the zenith distance rejection data may be the first test, followed by the horizontal angle rejection data, to judge whether to keep the horizontal angle data set.

The main problem with the manual collection method was the observer had no idea whether the data would pass the rejection tests while still in the field without querying the stored data, then processing it manually. Given the difficulty keeping track of the number of sets taken, this seemed an extreme request to ask the crew to do their own reductions in the field. It took no great revelation to come to the conclusion that operating the instrument via a hand-held computer could serve to control the instrument, collect the data, then analyze the data for suitability.

Since the Group has a number of Husky FS/2 hand-held computers, it was selected as the controller system. The FS/2 is a DOS 3.3 level PC using an 8088 processor work-alike. The FS/2 has 4-MB of semiconductor memory, of which 640KB is reserved for DOS, while the remainder acts as the C: drive. The system has BASIC, but since the Husky keyboard could never be mistaken for a programmer’s best friend, it was decided to do the programming on a standard PC using a formal development system, in this case Modula-2.

The first task was to write a driver that gave high-level access to the Geodimeter’s instruction set. While there were some tasks that could not be fully automated, such as programmatically selecting the Autolock function, setting units of measurement, and selecting the appropriate communications protocol, all other functions have been implemented. We did, however, run into a few unexpected ‘features’ that needed to be overcome, the most troublesome of which was not being able to use the D-bar mode programmatically while using the Autolock mode. This was overcome by emulating the process in software using the STD mode. The JOB File architecture, Geodimeter's observation storage strategy, was emulated using a linked list data structure, as was the AREA File architecture, the storage strategy for coordinate data. While not used in the current version of the program, the AREA File may play a role in automated search routines in the future.

The current version of the program accepts only a backsight and a single foresight. This was done to simplify the user dialog since the Group has only two RMTs at this time and the tunnel traverse has no side-shots. The program's object data structure will accommodate an infinite number of targets, memory limitations notwithstanding, subject to some minor changes in the operator dialog and, of course, an infinite supply of RMTs. The number of sets to be taken is user defined with the programmatic limit established at 40 sets to keep some sort of perspective on what automation should be doing for us. It should be noted that during testing, runs of more than 1000 sets were taken to test the robustness of the system. This was done using a traditional PC where disk space was not an issue.

In practice, the program dialog queries the user for salient information about the setup, the crew, heights of instrument and targets, meteorological data, followed by the filename selection dialog. The observer is next prompted to point the instrument at the backsight so that the approximate location may be *learned*. The *learn* process is repeated for the foresight. The program then takes over, pointing at the backsight, then foresight, then displaying the current statistics. Pointing is accomplished by using the instrument's Position command. This allows the input of a horizontal and vertical angle, along with an angular tolerance, in this case set to 25cc (8"). As soon as the tracker *sees* the RMT's signal, it takes over and performs the final pointing. After 75% of the specified number of sets have passed the rejection criteria, or the full number of specified sets have been observed, the observation cycle concludes and the observation statistics for the entire run are displayed.

The time required by the system to measure a single set, backsight and foresight, varies from about 18 seconds to about 115 seconds. This is due to the nature of the algorithm used to emulate the D-bar mode of observation. The routine samples the angle five times. If the standard deviation is less than the rejection limit, 2.5cc, the mean is accepted. Up to ten additional samples are taken until 75% of the samples fall within the rejection limit. If, after fifteen samples, the 75% criteria cannot be met, the mean is accepted, but will likely be rejected when compared to other sets. The typical set is completed in about 40 seconds. This translates to about 11 minutes of observing time for a sixteen set observing program.

The rejection process uses a *rolling mean* approach. This is done by calculating for all observations, finding candidate values for rejection, then rejecting only the most extreme value. The mean of the remaining pool of observations is then calculated, new candidates for rejection are selected, and the most extreme value is rejected. This continues until all members of the pool are within the range of the rejection limit from the mean.

Testing:

Testing is the most arduous part of deploying a new instrument. This is particularly so when it challenges the very threshold accuracy at one's disposal. Care must be taken and methods must be devised in order to minimize biases. Every care has been taken to prevent these biases from entering this process.

To test if the RMT emitter is 'stationary' with time, the question was divided into two parts: 1) can any meaningful change be discerned during the period of a single set of observations, and 2) is it stable over periods of weeks, months, or years? A method has been devised which obviates the need to determine the stability of the diode directly, however, to date, it has not been fully implemented.

In the interim, we have tested directly for phase error and apparent centering. First, each RMT was tested for phase error by rotating it around its vertical axis while observing whether any change in detected direction occurred. We tested this through a rotation of +/- 50g with respect to nominal azimuth without detectable change in azimuth. To test for centering, we transferred a line vertically from a reference point to the center of a 5/8"-11 stud using a Brunson. We then replaced the Brunson with the Geodimeter and placed the RMT on the stud. The reference point was sighted and the circle read. Finally, the Autolock system was allowed to acquire the RMT and the circle was read again. This setup was repeated several additional times with a deviation not greater than 0.05mm between the Brunson and the Geodimeter. To date, our findings show that any apparent movement of the emitter is statistically insignificant when compared to that of the positional uncertainty attributable to the Wild tribrach.

The method which we plan to deploy in order to test for and eliminate long term changes in the emitter, calls for inverting the RMT and measuring a second round of angles. If there is a lateral offset between the centering axis and the emitter's effective center, the position will change sides when inverted, thereby giving a measure of the value, as well as the means for eliminating the effect. Because the Geodimeter requires the distance to be measured in order to obtain the angles, there is certainly a minimum sight distance with which this will work, since the prism is offset vertically by 60 mm, juxtaposing the reflector and the emitter. If the manufacturer makes changes to the programmatic control of the Geodimeter, such that an angle can be observed without collecting a distance, then this method should eliminate any bias.

Our finding concerning the Wild tribrach is that the centering from one insertion of a device to the next insertion of that same device in the same tribrach, is not likely to be better than 0.15mm. This means that even though we are using the Wild NL to center over the point, when the NL is removed from that tribrach and any other tribrach-adapted device is mounted, it will not repeat mechanically better than this figure. Clearly, as the original inquiry suggests, a better centering system is required.

To test the sensitivity of the tracking system, we mounted the RMT on a cross-slide and moved it transversely by very small amounts while observing the change in direction displayed at the instrument. This was done with a sight distance of approximately four meters. The instrument displayed changes in angle at a level equal to our ability to measure the transverse movement with a dial-indicator. Once the tracker has acquired the emitter, there is no lost motion when changing the direction of travel.

There is some question about whether the tracker selects the center of the detector, or if it actually detects one side or the other of a region which is approximately 0.2mm wide, depending upon the direction of approach by the tracker. Our plan to minimize this effect, if it exists, was to rely on the inverting of the backsight and foresight RMTs, as described above. We expected to measure the station angle and the explement angle, approaching each RMT while moving in a clockwise direction. The plan made sense, however the total station out-smarted us. The servos always take the shortest path, either clockwise or counter-clockwise, between the two targets, so it is always moving through an angle less than 200g. We plan to make modifications to the driver such that it causes angles greater than 200g to be measured in a clockwise direction by having the servo make two moves of less than 200g each. This will allow the approach to the target to be from either side. Changes in the detector geometry, mentioned later, should render this issue mute.

While it was not a direct part of this test, it was found the zero-constant of the distance measuring unit of this instrument was long by 0.83mm +/- 0.18mm, when compared to the Mekometer, based on more than forty different lines. This seemed quite good for an instrument rated at ±(2 mm + 2 ppm).

Whether a system is productive, or not, can be measured in a number of ways. Certainly, if you can send the same people out to do a task, and they come back sooner with task completed, or they comeback with more work done, then it is clearly more productive. Also, if a crew can sustain a marginal rate of production for longer periods of time without becoming tired, or otherwise enfeebled, then the productivity potential is greater. And, if a less skilled crew can be sent in place of specialists, leaving the specialists for other, presumably more valuable tasks, then the productivity potential is greater, as well. Finally, if the latent productivity is defined as the untapped productivity inherent in a system, then the latent productivity in this system is quite high. The procedure currently in place has taken a rather minimalist approach, seeking operational feedback in order to define a final form. As this system matures, the likelihood of doubling current production rates is expected.

It is clear from this investigation that all of these measures of productivity are in play with this system. It is indeed the rare individual, who, as an E2 observer, has the eyes, the touch, the sense of urgency, and the stamina to compete with the total station. It is clear that it is possible to send a crew that has a marginal proficiency only slightly better than being able to do a proper job of setting over a point. The only issue remaining is whether the observer-E2 combination can be deemed competitive by producing a better quality product.

Results:

Much of the testing of this system has been on a time available basis. Comparisons of Geodimeter observations with E2 observations, as well as E2 observations with other runs of E2 observations, are the data used to base our conclusions.

Over the course of this investigation, thirty-nine Geodimeter angles were collected, of which three were rejected based on failure to comply with the rejection limit. During the E2-Mekometer traverse, eighty-four angles were observed, of which twenty-two were repeats. There were thirty-two Geodimeter-E2 comparisons, including the three angles that were rejected based on the 2.5cc criteria.

The comparisons yield the following statistics:

Average standard error of an angle:		
Kern E2	0.66cc +/- 0.21cc	(0.21” +/- 0.07”)
Geodimeter	0.46cc +/- 0.16cc	(0.15” +/- 0.05”)
Average difference in angle:		
E2-E2	0.53cc +/- 0.63cc	(0.17” +/- 0.20”)
E2-Geodimeter	0.59cc +/- 0.59cc	(0.19” +/- 0.19”)

These results indicate that the two instruments are comparable, at least in this application.

The Appendix A shows the good, the bad, and the ugly. A-1 is a typical set of observations with minimal rejections. A-2 shows a set of observations where the horizontal angles pass the rejection test, but the zenith distances indicate highly variable vertical refraction. A-3 shows a significant change in horizontal refraction for the backsight. The '*' indicates the rejected observations. The rejection limits used in these examples was 3.5cc.

The Future:

During discussions with Geotronics' agent from Finland, who is looking into tooling applications, it was suggested that it may be possible to employ a diode with an effective sensor width 1/10 as wide as the current version. This would be at the cost of useful target range, but for this application it would not be an issue.

Another technique discussed was that of using a 5mm aperture disk in front of the tracker's objective lens. This creates a *pin-hole camera* effect, which would provide the receiver diode with a sharper image. Again, this would likely limit the overall range, but enhance the system precision.

Other form factors of the RMT would certainly be welcome, for example, a 1-1/2" sphere with diode at the center, might prove useful. This would require an instrument that didn't require the distance to be measured when observing angles, but this seems a minor revision to the microcode of the Trig(ger) command.

Since the start of this investigation, Geotronics has introduced a new version of the RMT. Known as the Super RMT, its primary benefit is longer range and omnidirectional signal emission, at least for angles. No tests as to the suitability of the Super RMT in this application have been conducted.

Super RMT

In addition to the Super RMT, Geotronics has introduced a special commemorative edition of the 600 series, the Bergstrand, in honor of Dr. Erik Bergstrand, who developed the first Geodimeter in 1947. This instrument is a select system, offering an angular accuracy specification of 3cc and a distance accuracy specification of ±(1 mm + 1 ppm).

A new piece of instrumental software is also available. Known as Angle-Meas Plus - Program 32, it allows the observation of angles in both faces for as many as ten RMTs, for as many sets as desired. A production version of this program has not been evaluated.

Fixturing is a fertile ground for improvement. Plans call for creating a forced-centering system based on a pair of ¼" pin Hubbs nests and a 1-1/2" sphere. Tests of the RMT's leveling bubble sensitivity need to be done. However, a strategy that would allow leveling the inverted RMT is still to be worked out.

Finally, while it has not been the mission of this investigation, the system could prove to be useful as a refractometer, supplementing atmospheric observations made during Mekometer campaigns.

Conclusions:

It is clear that the Geodimeter can play on the same field with the E2. The differences in results between the Geodimeter and the E2 are at a level equal to that of comparisons between separate E2 runs. The rejection limit established in this investigation, although quite stringent, is achievable in this type of environment. It is also appropriate for weeding out unacceptable observations.

It is also clear that this is an extremely productive system, and that it can be made even more so, given subtle changes in the observing program and centering techniques.

Acknowledgments:

I would to take this opportunity to thank all the members of the SAG Group for their encouragement and assistance in this project. In particular, I would like to thank Gary Coppola, who gave his time and feedback to the development of this system. I would also like to thank the staff of Geotronics for their cooperation and counsel in this endeavor.

Appendix A

Pt	Horiz (gon)	vh (cc)	Zenith (gon)	vz (cc)	Distance (meters)	vd (mm)
	06/22/96		9:29:19			
186004	87.7911	-0.2	100.0431	0.8	60.3566	0.13
	87.7913	1.8	100.0428	-2.2	60.3564	-0.07
	87.7910	-1.2	100.0429	-1.2	60.3563	-0.17
	87.7911	-0.2	100.0430	-0.2	60.3563	-0.17
	87.7911	-0.2	100.0429	-1.2	60.3569	0.43*
	87.7910	-1.2	100.0429	-1.2	60.3568	0.33
	87.7909	-2.2	100.0428	-2.2	60.3568	0.33
	87.7909	-2.2	100.0430	-0.2	60.3567	0.23
	87.7913	1.8	100.0428	-2.2	60.3562	-0.27
	87.7912	0.8	100.0431	0.8	60.3563	-0.17
	87.7914	2.8	100.0430	-0.2	60.3563	-0.17
	87.7912	0.8	100.0433	2.8	60.3568	0.33
	87.7911	-0.2	100.0432	1.8	60.3562	-0.27
	87.7913	1.8	100.0432	1.8	60.3563	-0.17
	87.7910	-1.2	100.0431	0.8	60.3564	-0.07
	87.7911	-0.2	100.0432	1.8	60.3566	0.13
Mean/SD	87.7911	0.4	100.0430	0.4	60.3565	0.06
	16/16		16/16		15/16	

Inst: 186008
Angle= 207.41641 SE= 0.5 cc 186~40'29.18"
Dist= 60.35655 SE= 0.07 mm

Pt	Horiz (gon)	vh (cc)	Zenith (gon)	vz (cc)	Distance (meters)	vd (mm)
186343	295.2074	-1.4	100.0469	-2.0	49.6090	0.37*
	295.2073	-2.4	100.0467	-4.0*	49.6089	0.27
	295.2074	-1.4	100.0468	-3.0	49.6082	-0.43*
	295.2075	-0.4	100.0472	1.0	49.6084	-0.23
	295.2075	-0.4	100.0469	-2.0	49.6086	-0.03
	295.2075	-0.4	100.0470	-1.0	49.6083	-0.33
	295.2075	-0.4	100.0469	-2.0	49.6082	-0.43*
	295.2077	1.6	100.0471	0.0	49.6089	0.27
	295.2075	-0.4	100.0469	-2.0	49.6084	-0.23
	295.2076	0.6	100.0471	0.0	49.6088	0.17
	295.2077	1.6	100.0472	1.0	49.6086	-0.03
	295.2075	-0.4	100.0474	3.0	49.6087	0.07
	295.2076	0.6	100.0472	1.0	49.6087	0.07
	295.2077	1.6	100.0472	1.0	49.6082	-0.43*
	295.2076	0.6	100.0474	3.0	49.6085	-0.13
	295.2076	0.6	100.0473	2.0	49.6088	0.17
Mean/SD	295.2075	0.3	100.0471	0.5	49.6086	0.05
	16/16		15/16		12/16	

Pt	Horiz (gon)	vh (cc)	Zenith (gon)	vz (cc)	Distance (meters)	vd (mm)
	06/22/96		12:41:52			
186343	326.9923	-1.4	100.0757	-3.0*	54.0241	0.24
	326.9924	-0.4	100.0735	-25.0*	54.0246	0.74*
	326.9924	-0.4	100.0753	-7.0*	54.0238	-0.06
	326.9922	-2.4	100.0746	-14.0*	54.0239	0.04
	326.9922	-2.4	100.0747	-13.0*	54.0239	0.04
	326.9925	0.6	100.0759	-1.0	54.0240	0.14
	326.9925	0.6	100.0761	1.0	54.0239	0.04
	326.9924	-0.4	100.0768	8.0*	54.0236	-0.26
	326.9924	-0.4	100.0770	10.0*	54.0238	-0.06
	326.9926	1.6	100.0768	8.0*	54.0237	-0.16
	326.9926	1.6	100.0769	9.0*	54.0240	0.14
	326.9923	-1.4	100.0766	6.0*	54.0237	-0.16
	326.9924	-0.4	100.0765	5.0*	54.0239	0.04
	326.9925	0.6	100.0770	10.0*	54.0236	-0.26
	326.9926	1.6	100.0767	7.0*	54.0235	-0.36*
	326.9927	2.6	100.0767	7.0*	54.0241	0.24
Mean/SD	326.9924	0.4	100.0760	0.3	54.0239	0.04
	16/16		2/16		14/16	

Inst: 186012
Angle= 206.25456 SE= 0.6 cc 185~37'44.78"
Dist= 54.02417 SE= 0.06 mm

Pt	Horiz (gon)	vh (cc)	Zenith (gon)	vz (cc)	Distance (meters)	vd (mm)
186016	133.2467	-3.0	100.0725	-3.6	58.2251	0.11
	133.2466	-4.0*	100.0718	-10.6*	58.2250	0.01
	133.2467	-3.0	100.0721	-7.6*	58.2250	0.01
	133.2469	-1.0	100.0719	-9.6*	58.2247	-0.29
	133.2470	0.0	100.0719	-9.6*	58.2250	0.01
	133.2468	-2.0	100.0727	-1.6	58.2249	-0.09
	133.2469	-1.0	100.0730	1.4	58.2251	0.11
	133.2471	1.0	100.0738	9.4*	58.2250	0.01
	133.2471	1.0	100.0737	8.4*	58.2250	0.01
	133.2472	2.0	100.0739	10.4*	58.2250	0.01
	133.2473	3.0	100.0728	-0.6	58.2252	0.21
	133.2469	-1.0	100.0730	1.4	58.2253	0.31
	133.2472	2.0	100.0732	3.4*	58.2249	-0.09
	133.2470	0.0	100.0731	2.4	58.2249	-0.09
	133.2472	2.0	100.0729	0.4	58.2248	-0.19
	133.2470	0.0	100.0729	0.4	58.2249	-0.09
Mean/SD	133.2470	0.5	100.0728	1.7	58.2250	0.04
	15/16		8/16		16/16	

Pt	Horiz (gon)	vh (cc)	Zenith (gon)	vz (cc)	Distance (meters)	vd (mm)
186117	169.0230	12.9*	100.0662	3.4	68.9660	0.19
	169.0224	6.9*	100.0665	6.4*	68.9663	0.49*
	169.0221	3.9*	100.0663	4.4*	68.9658	-0.01
	169.0220	2.9	100.0661	2.4	68.9657	-0.11
	169.0219	1.9	100.0660	1.4	68.9658	-0.01
	169.0217	-0.1	100.0659	0.4	68.9658	-0.01
	169.0217	-0.1	100.0657	-1.6	68.9657	-0.11
	169.0216	-1.1	100.0657	-1.6	68.9660	0.19
	169.0217	-0.1	100.0657	-1.6	68.9656	-0.21
	169.0216	-1.1	100.0658	-0.6	68.9660	0.19
	169.0215	-2.1	100.0658	-0.6	68.9657	-0.11
	169.0213	-4.1*	100.0657	-1.6	68.9658	-0.01
	169.0211	-6.1*	100.0659	0.4	68.9657	-0.11
	169.0212	-5.1*	100.0657	-1.6	68.9658	-0.01
	169.0210	-7.1*	100.0660	1.4	68.9659	0.09
	169.0210	-7.1*	100.0658	-0.6	68.9658	-0.01
Mean/SD	169.0217	0.6	100.0658	0.6	68.9658	0.04
	8/16		14/16		15/16	

Inst: 186121
Angle= 209.19070 SE= 1.0 cc 188-16-17.87
Dist= 68.96576 SE= 0.07 mm

Pt	Horiz (gon)	vh (cc)	Zenith (gon)	vz (cc)	Distance (meters)	vd (mm)
186124	378.2121	-3.1	100.0754	2.7	51.7197	0.39*
	378.2130	5.9*	100.0754	2.7	51.7189	-0.41*
	378.2128	3.9*	100.0754	2.7	51.7191	-0.21
	378.2127	2.9	100.0754	2.7	51.7194	0.09
	378.2126	1.9	100.0754	2.7	51.7195	0.19
	378.2126	1.9	100.0752	0.7	51.7195	0.19
	378.2126	1.9	100.0752	0.7	51.7194	0.09
	378.2125	0.9	100.0751	-0.3	51.7193	-0.01
	378.2127	2.9	100.0749	-2.3	51.7193	-0.01
	378.2125	0.9	100.0750	-1.3	51.7192	-0.11
	378.2123	-1.1	100.0751	-0.3	51.7191	-0.21
	378.2123	-1.1	100.0748	-3.3	51.7193	-0.01
	378.2122	-2.1	100.0750	-1.3	51.7194	0.09
	378.2121	-3.1	100.0749	-2.3	51.7193	-0.01
	378.2121	-3.1	100.0750	-1.3	51.7193	-0.01
	378.2120	-4.1*	100.0749	-2.3	51.7193	-0.01
Mean/SD	378.2124	0.8	100.0751	0.7	51.7193	0.04
	13/16		16/16		14/16	