Application Note: Precision Calibration

INTRODUCTION

Straight out of the box, the FreeETarget circuit operates with relatively low calibration with no extra work. For those users who demand the best in accuracy, the target can be calibrated to remove errors due to assembly or other defects. This document describes the calibration and the steps needed to do this on the target.

REQUIRED EQUIPMENT

Item	Description	Required
1	Air Pistol Target	2 required
2	Suis target mask	2 required
3	Target Scan smartphone app	
4	Notepad or similar text editor	
	Alternate if you do not have TargetScan	
3A	Graph paper	2 required
3B	Thumbtack	1 required

THEORY OF OPERATION.

Aligning the paper needs to take care of the following sources of error

- Relative position of the paper to the sensors
- Angular orientation of the paper to the sensors
- Consistency in the location of the sensors

The calibration procedure takes care of these errors by comparing the calculated to the actual and applying a correction to each source of error.

An exaggerated sample of a paper target to the electronic target is shown in Figure 1. This shows a target with two holes (red) and two reported locations (black)

The four errors are:

- Static Position Error due to a misalignment between the paper and the sensors. This error will be consistent for each shot.
- Angular Position Error due to skew between the paper and sensors. This error will be consistent for each shot
- Radial Error, a difference between what the paper and the electronics support. This error may vary based on the position of the shot due to errors in locating the individual sensors

- Angular Position error, a difference between the location of the shot and it's computed value. This error may be based on how the sound travels to the sensor.

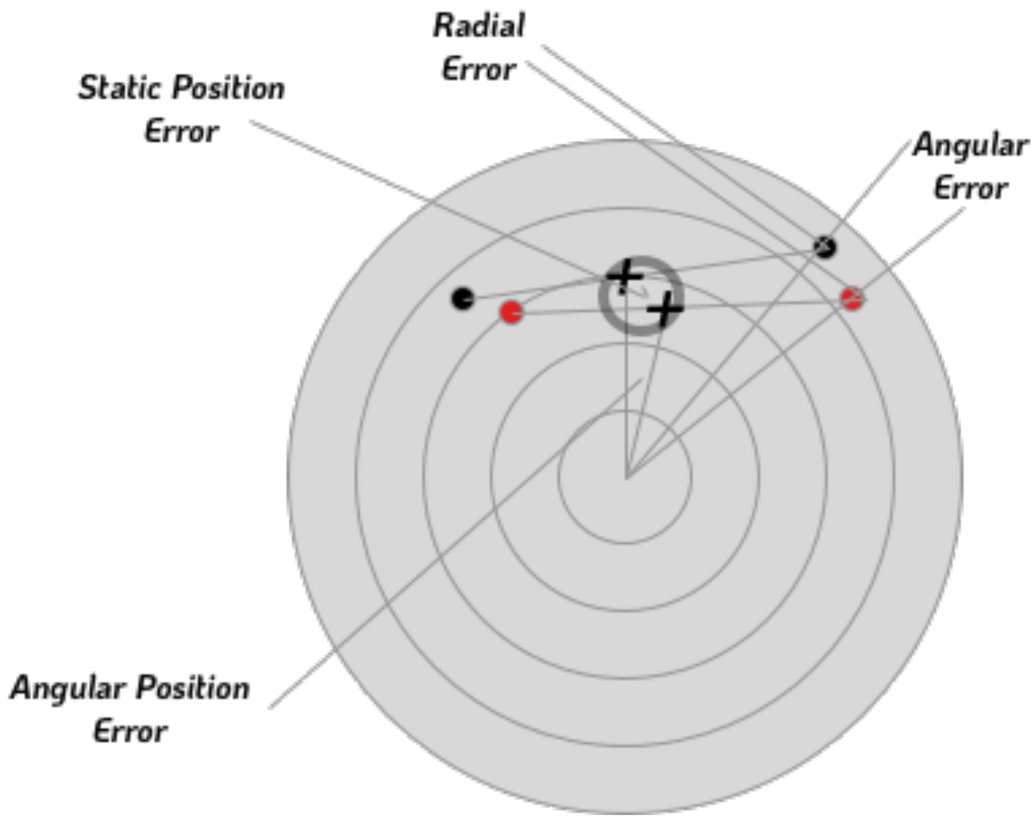

Figure 1. Target Error Sources

Static Position Error

The Static Position Error is eliminated by:

- Finding the geometric centre of the shots reported by the target
- Finding the geometric centre of the shots as recognized on the paper.
- Correcting for the difference between the two locations.

Static Angular Position Error

After shifting the shots to align the geometric centres of the actual to the paper shots, the Angular Position Error is eliminated by:

- Averaging the angular position of the actual target shots
- Averaging the angular position of the paper shots
- Adding the angular error to each new shot as it arrives.

Angular Error

The Angular Error occurs when there is a position error in the sensor that places the sensor out-of-round. This will skew the shots so that they appear uneven. The Angular Error is corrected by starting with a sample of (say) ten shots that can be compared between actual and target.

- Divide the circle of shots into arcs between the sample shots
- In each arc build a spline function that interpolates the angular difference between the two shots.
- As each shot arrives, determine which arc the new shots belongs to
- Determine the angular error and add it to the angular displacement of each new shot

Radial Error

The Radial Error occurs when the position error of the sensor is out of round and skews the shots so that they appear in an oval. Much the same as the Angular Error, the Radial Error is corrected by

- Divide the circle of shots into arcs between the sample shots.
- Correct each sample shot for the angular error calculated above
- For each arc, build a spline function that interpolates the ratio (scale factor) between the actual and target shots.
- As each new shot arrives, determine which arch the shots belongs to
- Multiply the computed radial displacement by the spline computed scaling factor

CALIBRATION PROCEEDURE

The calibration procedure is done in the following steps:

- Prepare the calibration by resetting all the internal calibration constants
- Take twenty (20) sample shots
- Measure the shot location using Target Scan or similar
- Using Target Scan, enter the X-Y location of each of the ten sample shots
- Enter these into target and let it calculate the calibration values
- Save the calibration values into the target

All of these steps can be carried out using the debug tab on the PC client.

Prepare the Calibration

Start by carefully locating the centre of the two paper target in the centre of two Suis mask.s as shown in Figure 1. It is important that this be done precisely since an error here will translate into the final calibration.

Figure 1: Target and Mask Assembly

On the PC with the Client

- Open the PC client
- Connect to the target
- Press the Debug tab to observe the target as you shoot
- Send the command {“CAL”:1} to the target. This removes the current calibration and prepares the software to accept the data.

Take Twenty Sample Shots

Take twenty sample shots. Ideally the shots need to land in a circle in the four ring. As shown in Figure 2, you want to spead the shots out across the target as much as possible.

DO NOT EXIT THE PC CLIENT UNTIL CALIBRATION IS COMPLETE, OTHERWISE THE SHOT DATA WILL BE LOST.

Target Scan

For both targets, remove the target from the Suis mask and read them into Target Scan. If you do not have Target Scan, then refer to the alternate steps in Appendix 1.

Export the Target Data

Using the upload icon at the bottom of the Target Scan Page (lower left square with an up arrow) email the Shots Data to yourself (Figure 2)

The shot data is a CSV file that can be observed using Excel or some other spread sheet. The target data is shown in Figure 3.

Figure 2: Sending Shots Data

TargetScan Data

Shot Number	Scan Number	Score	x	y
1	1	7.7	-21.03	-15.66
2	1	6.9	-15.21	-28.20
3	1	6.5	-11.33	-33.89
4	1	6.4	-17.67	32.17
5	1	6.3	30.30	-21.61
6	1	4.9	23.84	42.26
7	1	4.3	36.51	-38.42
8	1	4.1	-34.60	-42.56
9	1	3.9	-51.80	22.48
10	1	3.0	16.47	-61.17
11	2	9.8	-0.24	-9.43
12	2	7.8	-8.49	-23.85
13	2	7.1	22.33	-20.86
14	2	6.8	28.63	17.05
15	2	6.6	-26.95	21.98
16	2	5.8	-41.04	-6.76
17	2	4.6	-50.76	0.22
18	2	3.9	-55.14	10.89
19	2	0.0	19.04	78.51
20	2	0.0	-56.24	-61.51

Figure 3: Target Scan Data

Prepare the Target Values

Using Notepad or a similar text editor, record the test results EXACTLY as shown

{“CAL”:2, [x1, y1, x2, y2, ….] }

Where Xn and Yn correspond to the XY coordinates you recorded from the CSV file.

Taking the example as shown in Figure 3, the input would be:

{"CAL":2, [-21.03, -15.66, -15.21, -28.20, -11.33, -33.89, -17.67, 32.17, 30.30, -21.61, 23.84, 42.26, 36.51, -38.42, -34.60, -42.56, -51.80, 22.48, 16.47, -61.17, -0.24, -9.43, -8.49, -23.85, 22.33, -20.86, 28.63, 17.05, -26.95, 21.98, -41.04, -6.76, -50.76, 0.22, -55.14, 10.89] }

Note that the misses (0) are not entered into the program.

IMPORTANT

The list of numbers begins and ends with square brackets [ ].

Calibrate the Target

Copy the text ({“CAL…} into the COMMAND as shown in Figure 4 and press Send

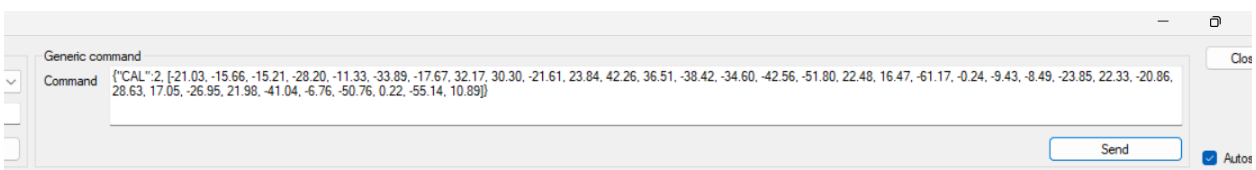

Figure 4: Calibration Command Line

The target will match up the target scan data to the shot data and keep the ten shots furthest way from the 10 ring. It will then generate a series of calibration constants that will be used to adjust the shots.

At the end of the calibration, you will be prompted to save the settings. Clear the command box and enter Y then send.

The target should now be calibrated.

Erasing the Calibration

If you make a mistake in the calibration, you can clear the calibration by sending the command {“CAL”:8}. You will be prompted to confirm that the calibration should be cleared.

APPENDIX 1

ALTERNATE CALIBRATION METHOD

If you do not have Target Scan, you can use an alternate calibration method using graph paper.

Using a thumbtack or pin, align the centre of the target to the centre line of the graph paper as shown in Figure A1

Figure A1. Graph Paper Alternative to Target. Scan

- Tape the target to the graph paper
- Attach the target and graph paper to the target as you would normally
- Shoot 10 shots into the target/graph paper
- Change to a second target/graph paper and repeat
- Carefully locate the centere of each pellet hole
- Write down the X-Y coordinates of each centrepoint
- Use these coordinates for the {"CAL":2… } command