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Sokkia FX-103 Total Station Survey Guide using Survey Pro 6.6 for Live-Fire Experimentation

prepared by Jarid M Kranz Sr
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103 Bata Blvd
Belcamp, MD, 21017

under contract W911QX-17-C-0021

NOTICES

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14. ABSTRACT
This report details step-by-step instructions on how to use the Sokkia FX-103 Total Station paired with a Sokkia SHC5000 data collector utilizing the program Survey Pro 6.6 for large-caliber live-fire experimentation. The primary focus is toward current and new range personnel with little to no live-fire range layout and setup experience. Concepts such as typical range layout, initial total station setup, occupy points, and shot-line setups are explored.

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Contents

List of Figures

1. Introduction

Typical ballistic live-fire expirements require the use of survey equipment to establish common data points such as the 1) shot line, which describes the line from the barrel exit to the target, 2) radar location, and 3) high-speed video (HSV) locations. As HSV resolution has increased, the ability to capture a projectile's spatial and attitudinal coordinates has improved, requiring an expanded use of survey equipment to setup multiple reference fiducials for firing programs with advanced positional requirements. This report details examples and steps required to setup a typical firing program using a Sokkia FX-103 Total Station (Fig. 1) with Survey Pro software.

Fig. 1 Sokkia FX-103 Total Station

2. Total Station Setup

Ensure the lithium ion battery for the Total Station and the data collector is sufficiently charged before use. Refer to Appendix A for identification of the different parts of the Total Station prior to use. Initial training and a working knowledge of the system and components (Appendix A) is recommended prior to use to prevent damage to the unit. The system is sensitive and caution is suggested during initializing and operation. Prior to setup, a review and understanding of the test plan is recommended, and survey data information can be obtained from the test engineer/director. This will provide an expeditious execution of collecting the survey data. A sample range layout is shown in Fig. 2. This layout shows the gun

target line as it relates to the barrel and target, a radar system, and multiple high-speed video cameras with backdrops (if needed) covering the field of view.

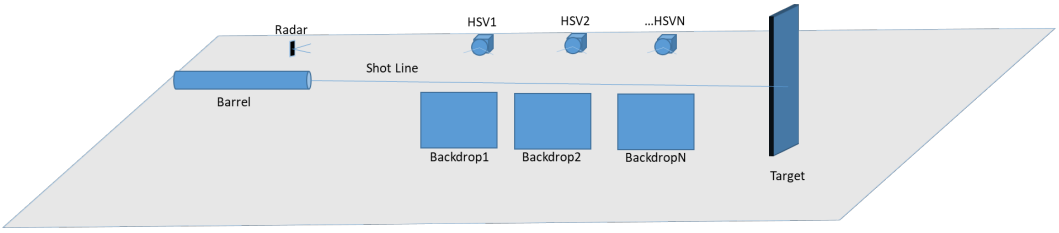

Fig. 2 Typical large-caliber test setup

1) Find a location where all points are visible, or as many as possible. Ideally, all points will be surveyed from one spot; however, there may be times where more than one setup point is necessary. Ensure the shot line is visible from every setup location to establish a common reference point so all subsequent points can be referenced for accuracy.

2) Set up the tripod and make sure that the tripod legs are spread apart in a manner to make a stable platform for the Total Station. Level the tripod with a 360° level (most smartphones have one preinstalled, and is accurate enough for this step). This will allow for easier leveling of the Total Station head. Also be mindful of the height so the Total Station is not too low or high when placed upon the tripod for user preference.

3) Secure the Total Station to the tripod using the tripod's mounting screw and turn it on. Level the Total Station using the onboard display level and leveling foot screws so *x* and *y* are at 0'00". Then the data collector is ready to be set up.

3. Data Collector Job Setup

This section describes survey job setup. It is important to name the file so the collector can easily catalog and revisit the job if needed. It is also important if there are multiple jobs for the same program. Press the power button on the data collector to turn on (hold the button until you see the boot screen).

1) Once the data collector has initialized, open the Survey Pro application.

2) Tap the "New…" button to start a new survey (Fig. 3).

3) Type in New Job Name: dd-mm-yyyy and program name.

4) Tap Settings >.

5) New Job:

a. Azimuth type: north azimuth

b. Grid direction: north and east

c. Units for distances: meters

d. Units for angles: degrees

e. Refraction coefficient: none

6) Tap Next.

7) Check “No control or reference file”.

8) Tap Next >.

9) Uncheck “Select Coordinate System”.

10) Tap Next >.

11) Uncheck “Enter First Point”.

12) Tap Finish.

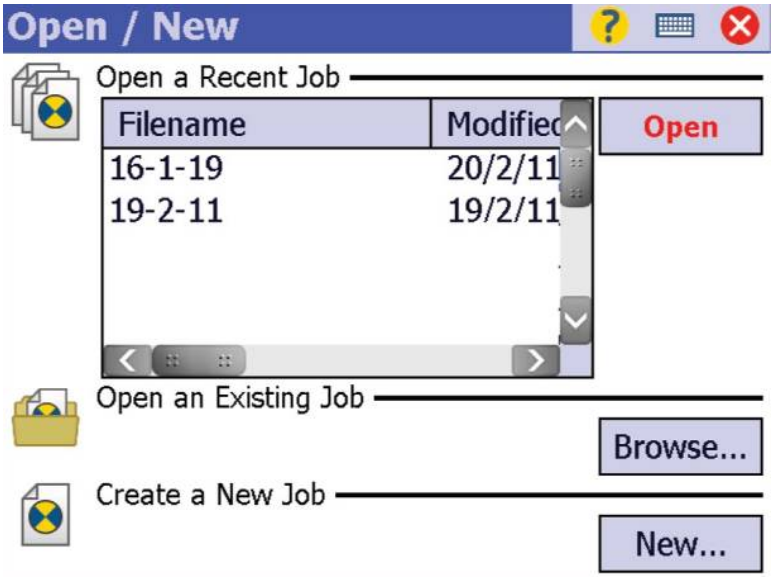

Fig. 3 Open/new screenshot

4. Transit Backsight Setup on Data Collector

This section explains how to establish an “occupy” point (the point in space the Total Station occupies) and a Backsight (BS) point to orient the Total Station (so the Total Station knows where it is in space). The BS will serve as the origin point, and the first of two points represent a theoretical line pointing from the muzzle to

the target, the shot line (Fig. 4). This line shows the test setup based on the placement of instrumentation, yaw cards, and other parameters pertaining to the test in Fig. 5.

13) Tap and confirm “FX-103 TEF” is checked.

14) Tap “Station Setup”.

15) Station Setup:

    a. Setup Type: Known Point

    b. + Occupy Point: Type “Transit”

    c. Uncheck 2D Survey

    d. HI (height of instrument): Type “0.000”

16) Tap “Create New Point”.

17) Insert Point:

    e. Point Name: Type “Transit”

    f. Description: Leave blank

    g. Code: Leave blank

    h. Layer: Points

    i. Picture: <None>

18) Tap .

19) Tap Next >.

20) Select from top left drop down “New Point”.

21) Select BS azimuth from next dropdown and type “0.000”.

22) Select Fixed Target from bottom dropdown.

23) HR (height of reflector): 0.000m, and dropdown to right select My Reflectorless (if using a sticker) or My Prism (if using a prism).

24) Uncheck Perform Backsight Repetition Set.

25) Tape sticker or have second person hold prism on BS point. If using the muzzle of a gun, make sure the sticker or prism is in the center.

26) Aim the Total Station at the BS point (normally the center of the muzzle or the point you want as your origin) using the peep sight and telescope eye piece.

27) Tap Measure & Set >.

28) Station Setup:

    a. Point: Type “Shotline1”

    b. Description: BS

29) Tap ✔.

30) Tap Finish.

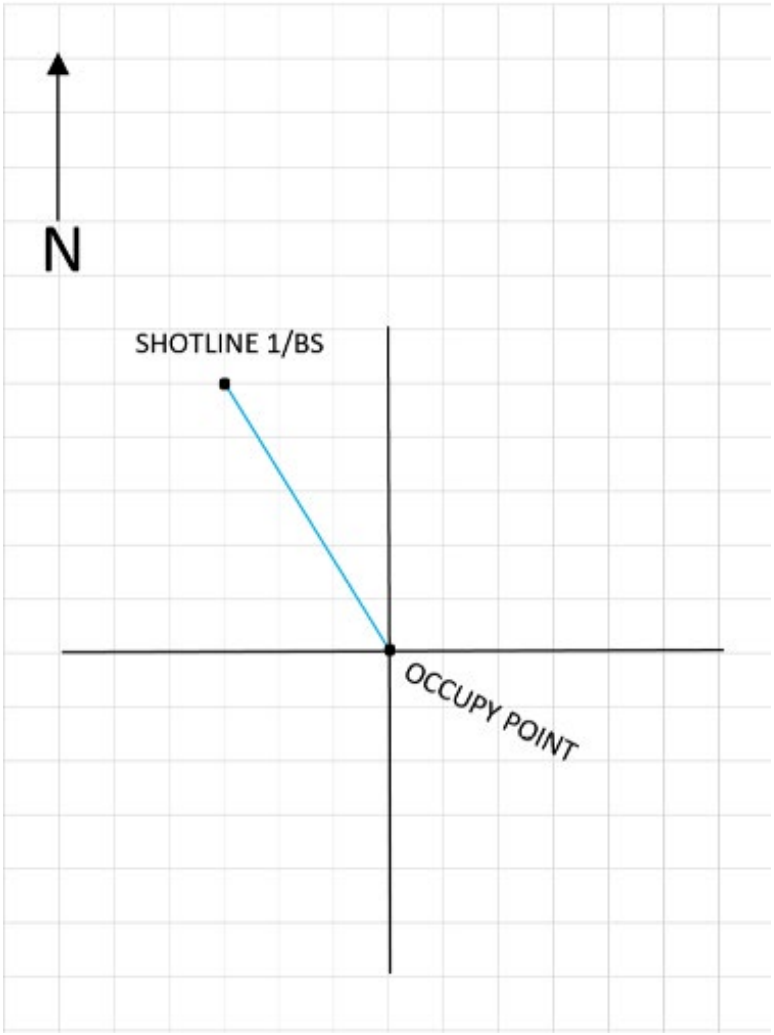

Fig. 4 Graph illustrating first two points

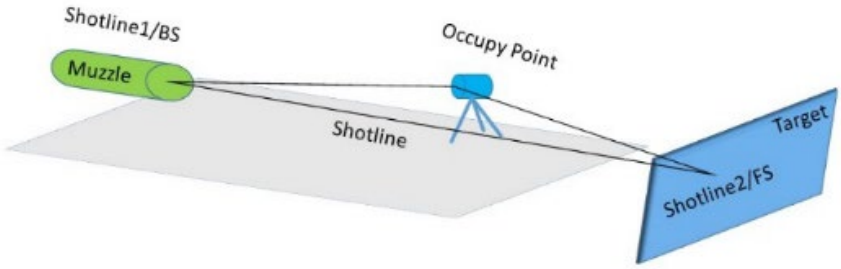

Fig. 5 Graphic representing the first three points

5. Establishing the Foresight

This section describes establishing the Foresight (FS), a third point in the survey process that will make up the second point of the shot line, thus completing the path in Figs. 4 and 5. This will establish the three points necessary to translate and rotate points in the next section (Fig. 6).

31) Tap Traverse/Sideshot.

32) Traverse/Sideshot:

   a. FS: Shotline2,

   b. HR: 0.00.

33) Aim the Total Station at prism or sticker downrange using the peep sight and telescope eye piece.

34) Tap Sideshot.

35) Tap ✔.

36) Tap ✖.

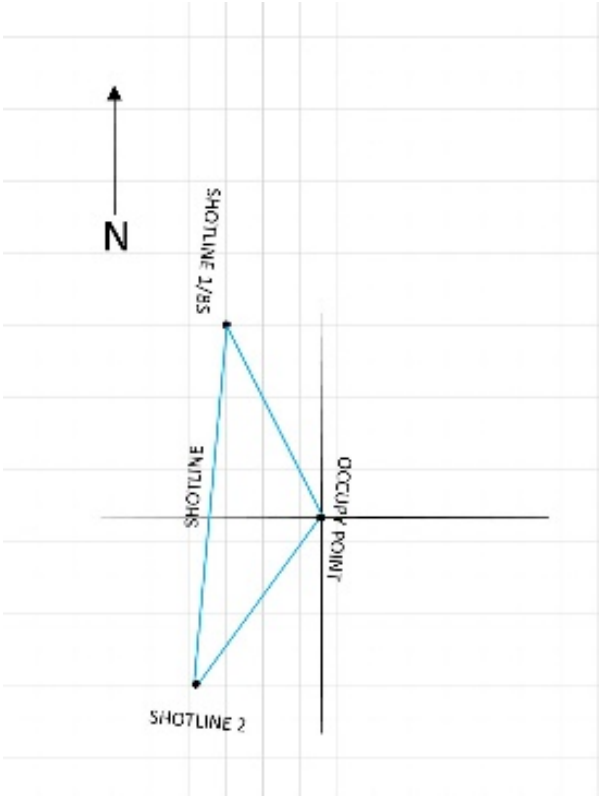

Fig. 6 Graph illustrating first three points

6. Translate and Rotate Points

This section describes translating (moving) the "occupy" origin point coordinates (0,0,0) from the Total Station to Shotline1 (Fig. 7). The points are then rotated to a 90° azimuth so the coordinate system is positive moving downrange (forward of Shotline1), making the coordinates easier to read (Fig. 8).

37) Tap .

38) Tap Adjust.

39) Tap Translate.

40) From dropdown, tap "Select all Points". (Should say "3 points selected".)

41) Check Translate by Coordinates.

42) Left pane dropdown, select by point.

43) Left pane bottom dropdown, select choose from list.

44) Tap Shotline1.

45) Tap ✓.

46) Right pane dropdown, select by location.

47) N: 0.00, E: 0.00, Elev: 0.00

48) Tap Solve.

49) Tap ✓.

50) Adjust Selected Points? Tap yes.

51) Auto backed up. Tap ok.

52) Three points have been rotated. Tap ok.

53) Tap ⊗.

54) Tap Rotate.

55) Rotation Point from dropdown, select from list. Tap Shotline 1.

56) Tap ✓.

57) Check old and new azimuths.

58) Old azimuth from dropdown, choose from list.

59) Tap Shotline1.

60) Tap ✓.

61) Tap Shotline2.

62) Tap ✓.

63) New Azimuth: 90°

64) Tap Solve.

65) Adjust Selected Points? Tap yes.

66) Archive “ADJ_ROTATE” has been auto backed up. Tap ok.

67) Two points have been rotated. Tap ok.

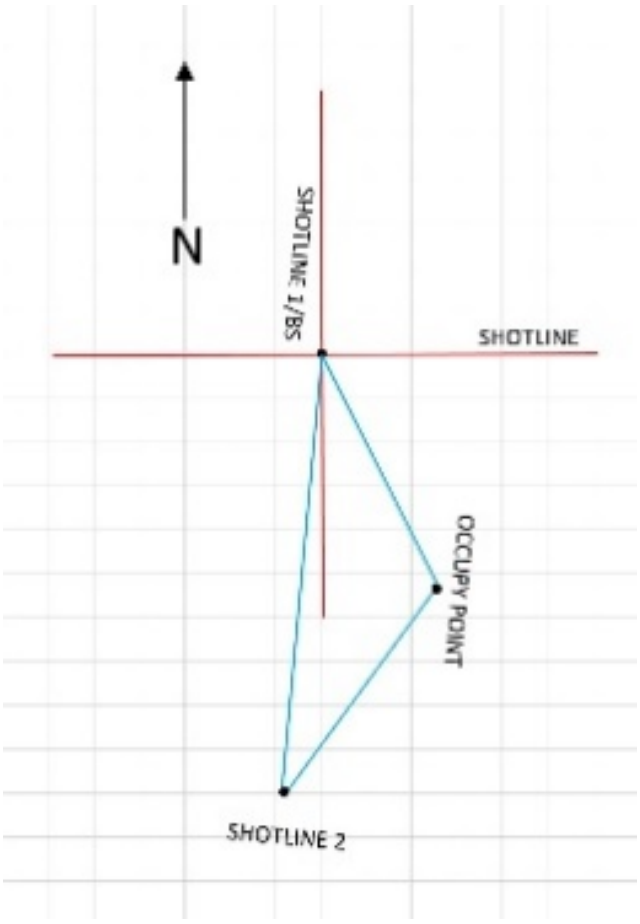

Fig. 7 Graph illustrating coordinate change

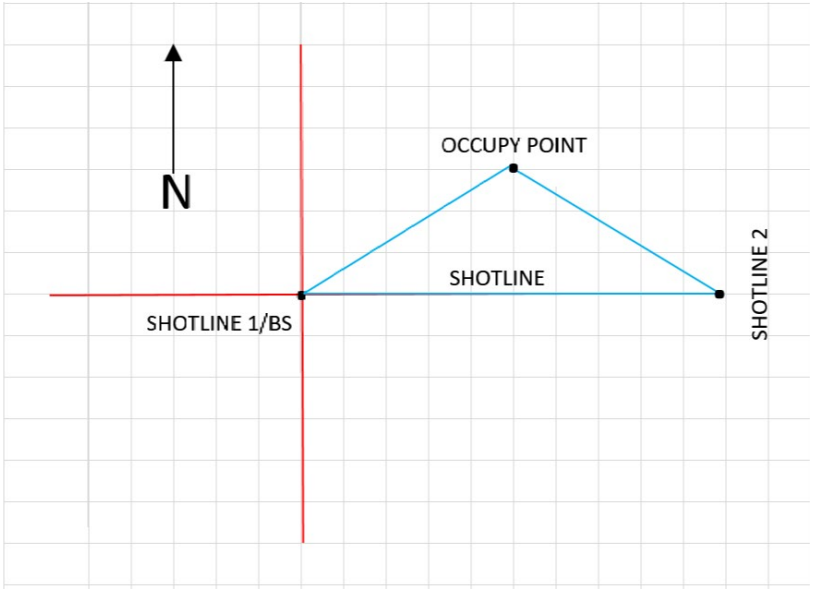

Fig. 8 Graph illustrating rotating points to a 90° azimuth

7. Verifing Adjusted Points

This section confirms the adjusted points from the previous section. If confirmation is verified, proceed to Step 73.

68) Tap .

69) Tap .

70) Tap Job.

71) Tap Points.

72) Verify Points (Shotline 1 should have a northing of 0.000, easting of 0.000, and an elevation of 0.000. Shotline 2 should have a northing of 0.000, easting of x.xxx (x.xxx represents values of an actual point), and an elevation of x.xxx). Tap .

8. Re-establish Backsight

When the points are adjusted, the Total Station no longer knows where it is located in space. The occupy point must be re-established by reshooting the Shotline 1 BS point (Figure 7).

73) Tap .

74) Tap Survey.

75) Tap “Station Setup”.

76) Setup Type: Known Point, + Occupy Point: Transit (from dropdown, choose from list).

77) Tap Transit.

78) Tap .

79) Uncheck 2D Survey, HI: 0.000m.

80) Tap Next >.

81) Top dropdown, tap BS Point; right dropdown, choose from list.

82) Tap Shotline 1.

83) Tap .

84) Tap Next >.

85) Tap dropdown for Fixed Target.

86) Aim the Total Station back to muzzle center or origin point using the peep sight and telescope eye piece.

87) Tap Measure and Set.

88) Tap Finish.

9. Surveying Additional Points

This section describes how to survey additional points. Establishing additional points during setup and the number of additional points will depend on the surveying requirements for the test. As described earlier, read the test plan prior to setup and determine the survey points based on the test plan.

89) Tap Traverse/Sideshot.

90) FS: (name of object to survey [target, camera, 50 m, etc.]), HR: 0.000, tap right dropdown and select my prism or my reflectorless.

91) Aim the Total Station on sticker or prism using the peep sight and telescope eye piece.

92) Tap Sideshot.

93) Tap .

94) Repeat Steps 89–93 for each additional point.

10. Exporting Job to Comma Separated Values (.CSV) File

This section describes how to export the survey results to a comma separated values (.CSV) file. The data is exported into a simple format that can be accessed by various programs, but Excel is commonly used.

95) Tap .
96) Tap .
97) Tap File.
98) Tap Export. Select Type of File to Export: Tap dropdown and tap Comma Separated Values (.CSV) File.
99) Select the Points to Export: Tap dropdown and Tap Select all points.
100) Tap Next >.Coordinates: Tap Plane, Uncheck headers in the first row. Tap Next >.
101) Next Tap Name, Northing, Easting, Elev., Desc., Code, and Attr. Then Tap Export. Tap .

11. Moving a Point in Survey Pro

This section shows how to move a point to a known location where it cannot be visibly seen, such as the trunnion center point of a large-caliber gun system. This allows for verification of the elevation of the gun system as well as verifying scope aim.

1) Tap Adjust in “Main Menu”.
2) Tap “Translate”.
3) Tap “From Map”.
4) Tap on point that needs to be moved.
5) Tap .
6) Check the box “Translate By Coordinates”.
7) Tap left dropdown in lower left pane.
8) Tap “Choose From List”.
9) Tap the point selected on map.
10) Tap .
11) In the lower right pane, tap “Location▸Location”

    N:x.xx

    E:x.xx (x.xx represents a value entered)

    Elev:x.xx

    The operator needs to know the location the point is to be moved to. With the center trunnion point, an initial point to find the distance from the muzzle to the trunnion while the gun system is at true level (0 mil on quadrant) is needed. The gun system should also be on required azimuth using the scope as well.
12) Tap “Solve”.

12. Change Origin Point to Trunnion in Survey Pro

Translate and Rotate section process. If the origin point needs to be changed in reference to the trunnion, it allows the operator to change that origin point based on the 90° azimuth previously established in the “Translate and Rotate” section.

Generally, the placement of instrumentation is based off of the muzzle, but it may be necessary to change the origin point for elevation and scope verification due to testing issues.

1) From “Main Menu” tap “Adjust”.
2) Tap “Translate”.
3) Tap dropdown in upper pane.
4) Tap “Select All Points”.
5) Check box for “Translate By Coordinates”.
6) Tap “Point”. Then tap lower-left dropdown menu.
7) Tap “Choose From List”.
8) Tap trunnion.
9) Tap ✔.
10) In lower-right pane enter N:0

    E:0

    Elev:0

11) Tap “Solve”. The screen will display “your selection contains these critical points” with points listed. Just tap ✔.
12) Tap “Yes”.
13) Tap “Ok”
14) Tap “Ok”
15) Re-establish BS in “Station Setup” within the “Survey” menu.

Appendix A. FX-103 Total Station Parts


TELESCOPE EYE PIECE
VERTICAL FINE MOTION SCREW
BATTERY COVER
TOUCH DISPLAY
LEVELING FOOT SCREW
HANDLE SECURING SCREW
TELESCOPE FOCUSING RING
VERTICAL CLAMP
OPERATION PANEL
TRIBACH CLAMP


INSTRUMENT HEIGHT MARK
OPTICAL PLUMMET EYEPIECE
HORIZONTAL CLAMP
OBJECTIVE LENS
PEEP SIGHT
HORIZONTAL FINE MOTION SCREW

Appendix B. Background Information on Range Setup and Survey Use

A graphical description is shown (Fig. 5 in the main report) to demonstrate a representation of the first three points captured with the transit. By establishing an occupy point, a Backsight (BS) and a Foresight (FS) point create a triangle. The BS and FS points create the theoretical path the projectile will travel during flight known as the “Shotline”. The Shotline establishes the instrument setup locations and are labeled “Shotline1” (BS) and Shotline2” (FS). The three points create a triangulated position establishing the known point for the transit location.

The FX-103 Total Station uses an extremely accurate laser (2 mm/km) to measure distance to an object of interest. When the occupy point is created, the transit becomes your origin point 0,0,0 (Fig. 5, main report). The BS point at the center of the muzzle is established and becomes the new fixed reference point. This establishes the first side of your triangle. The muzzle normally does not change in azimuth, but the elevation can change from shot to shot. The third reference point is the FS point, normally on the target, and establishes the second Shotline point, Shotline2. This is a reference point that does not change position. The third point will make up the second and third sides of the triangle also creating the newly referenced Shotline in the process. When these three points are translated (Fig. 6, main report) and rotated (Fig. 7, main report), it makes Shotline1 and Shotline2 a straight line on a 90° azimuth, with Shotline1 being the new origin point 0,0,0 and Shotline2 being the target at the measured coordinates from the range, 0, x.xxx, x.xxx. If Total Station setup is required at multiple locations due to geometry not allowing all points being visible to the transit, the newly set up Shotline will be the reference for the additional setup locations so all coordinates use the same reference, even though the transit is setup in another location.

Appendix C. Verifying Quadrant or Obtaining Mil Reading Using Survey Pro Data and Ti-89 Calculator

In Survey Pro:

1) Tap .
2) Tap and hold on first point for a second, then release. (Alt click menu should appear.)
3) Tap “Point to Point”. (A red dot should appear on the point selected.)
4) Tap second point. (Usually a crosshair point visually marked on a yaw card using a scope and level, then surveyed.)
5) Tap and hold on “Inverse_____to_____ for a second, then release. (Alt click menu should appear.)
6) Tap “Show results”.
7) Write down the Horz Dist: x.xx

   Vert Dist: x.xx

   Slope Dist: x.xx

On TI-89 calculator, find Angle A (Fig. C-1).

17.77 mil = 1° SINA=$\frac{a}{c}$

1) Type a÷c enter = SINA.
2) Type ◆ SIN-1(SINA) enter = ∆ A.
3) Type ∆ A × 17.77 enter = mil

Horz Dist: x.xx = b

Vert Dist: x.xx = a

Slope Dist: x.xx = c

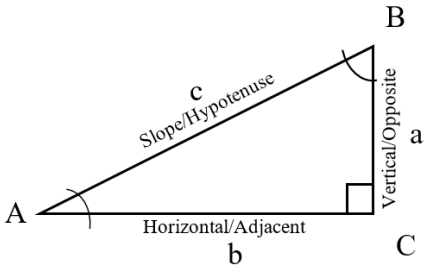

Fig. C-1 Right triangle reference

List of Symbols, Abbreviations, and Acronyms

BS	Backsight
.CSV	comma separated values
FS	Foresight
HI	height of instrument
HR	height of reflector
HSV	high-speed video

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