

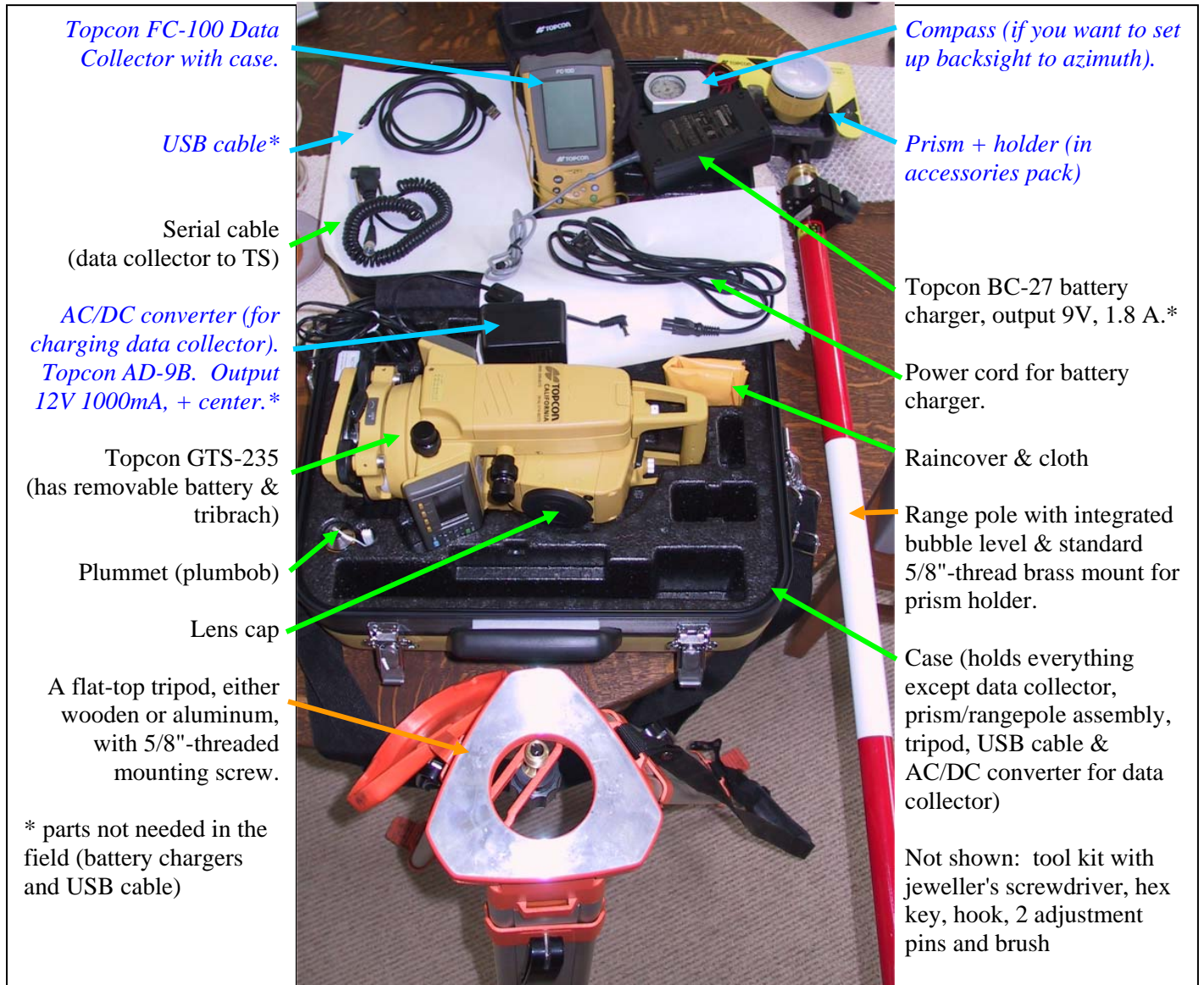
# Topcon GTS-235 Total Station

## Guide

--Jerry Davis, San Francisco State University IGISc

This guide is intended for using SFSU *Institute for Geographic Information Science* Topcon GTS-235 total station (TS) to measure coordinates and recording the values in a data collector.

First, a checklist to make sure you have everything you need:



### Parts to carry:

1. Yellow case with total station, serial cable, plumbob, raincover, BC-27 battery charger for total station, power cord, tool kit.
2. *Tamrac accessories pack with prism, data collector, USB cable, AD-9B AC/DC, and prism holder (shown in blue italics above and on next page)*
3. Range pole with 5/8" mount
4. Flat-top tripod

## Topcon Total Station Accessories Pack (Tamrac digital camera bag)



### Instrument Setup

1. Make sure tripod legs are securely tightened and well set into ground surface, and that upper mounting plate is as level as possible before mounting instrument. On sloping ground, have one leg upslope. Carefully mount the instrument with the screw from the tripod. *If you are going to occupy a benchmark, position the instrument as near as possible over the benchmark; you should use the plumbob to get it close (within a centimeter or so) – you'll be able to get it closer after leveling using the laser plummet. You should remove the plumbob before continuing.*












### **Packing the Total Station**

The total station is a sensitive instrument. When packing the total station in the case, make sure to unlock the horizontal and vertical controls so they turn freely.

2. Identify the components you need to use:

a) The *tribrach* at the base, which contains three leveling screws and a circular bubble for coarse leveling. There's also a lock which you can undo to release the tribrach, but you won't need to do this.

b) Two identical LCD *display units* with:

-  Power
-  MENU Menu
-  ESC Escape
-  ENT Enter
-  Star
-  Star
-  NEZ coordinate mode
-  Horizontal distance mode
-  ANG Angular measurement mode
-  left-right and up-down
-  F1 F2 F3 F4 Function buttons used for menu choices.

c) A sighting telescope with eyepiece and lens sides. Focus is the outermost brown circle, with the cross-hair focus the tiny black ring around the eyepiece. Above the telescope is a rough sighting collimator with a triangle visible inside.

d) Horizontal and vertical control knobs: larger **motion clamps** which are loosened for free movement and coarse adjustment, and tightened for fine adjustments with the **tangent screw**, mounted on the motion clamp. Located beside and above one of the display units and to the lower left of the telescope lens. *If it's on the eyepiece side, loosen the vertical motion clamp and rotate the telescope 180° to get the lens on the clamp side – this is called the direct reading, and is required for the data collector to work.*

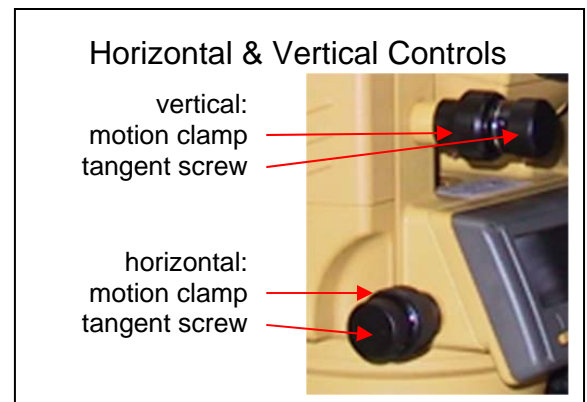
e) Plate bubble level, mounted above one of the displays.

f) A battery in the post to the left of the vertical control. The battery can be released with a button on the top.

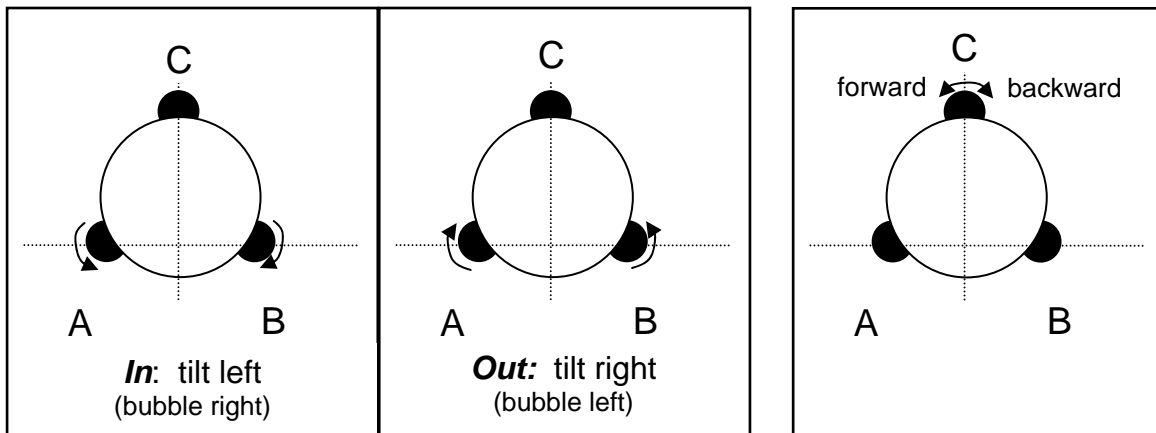
g) There are other parts like the laser plummet you shouldn't mess with, and signal and power ports which you'll use later.



Check the battery level. You need to charge it before using it.



**3. Coarse-level the instrument** using the bubble level on the tribrach. *Tip:* Start by positioning yourself in line with one of the adjustment knobs (C), with the other two knobs (A & B) forming a perpendicular (see figure below). Then simultaneously adjust A & B to tilt the instrument to the left or right; always turn them together either *in* or *out* from your perspective – you'll be turning the knobs in opposite directions, but think *in* or *out*. Once centered left to right, use the third knob *C independently* to center the bubble front to back. You may have to do the left-right centering again, etc. *You can also do this with one knob (C) towards you.*



**4. Fine-level the instrument.** Use the 30" (30 seconds of angle) plate level above one of the LCD displays to do a fine adjustment. You'll use the same adjustment knobs, but you will need to (loosen the horizontal motion clamp and) rotate the instrument parallel to the left-right axis, then parallel to the front-back axis, to do each of those adjustments. You'll notice that the adjustment is very sensitive, requiring tiny movements, and the bubble moves slowly to its stable reading – wait 5 seconds for it to adjust each time before you adjust any more. Check the level in all four directions by rotating 90° each time. *If your tripod is not mounted on stable ground, you'll never get it leveled.*

**5. If occupying a benchmark, reposition over the benchmark using the laser plummet.**

Note: One method that may make it easier to position over the benchmark is to remove the instrument from the tribrach while positioning the tribrach over the point. Since it's locked, you'll need to unlock it by first using the small screwdriver in the toolkit to undo the safety on the lock, then unlocking and removing the instrument (carefully)

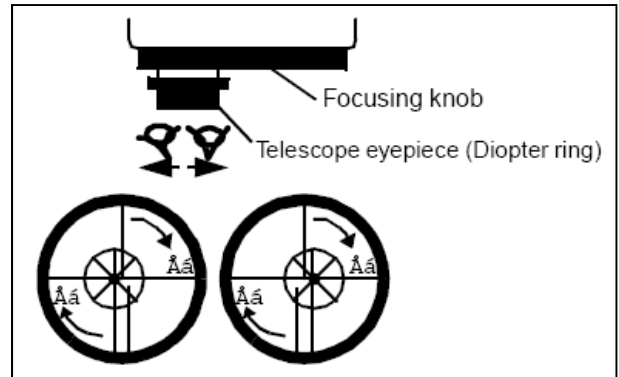
- Power up the display. Wait a few seconds for the initial and contrast settings to display, followed by the normal angle mode display (V and HR values displayed).
- Press the star key to get to the star menu, and select the laser plummet with F4. The laser plummet will then illuminate a visible red dot on the ground.
- Loosen the tripod screw to position the dot on the benchmark; then tighten the screw.
- Turn off the laser plummet to save power.



**6. Extra-fine leveling using the tilt sensor.** You can use the internal tilt sensor to get it leveled even better. (If not already on, power the instrument up and wait for the normal angle mode display.) Use the Star menu, then F2 to select the tilt sensor. Initially the X-On (F1) mode is on, which you use to make *tiny* adjustments to the front-back tilt – the goal is to get it within 5" of 0. Then select XY-On (F2) to adjust the right-left. From here you can also make more front-back adjustments. F4 lets you check the laser plummet if you want.

### How to Collimate:

1. Point the telescope toward a bright surface, like a blank white sheet of paper held in front. Adjust the diopter ring (closest to your eye) to focus the cross hairs.
2. Aim the target roughly using the sighting collimator, with the target at the peak of the triangle in the sight.
3. Focus the target with the focusing knob.



from Topcon GTS 230 series manual

You may want to check for parallax by shifting your eye slightly when focused on a distant object (> 200 m). If it moves, adjust the diopter and focus further to eliminate parallax error.

### What this *Guide* provides, and what are in other documents

#### **This *Guide*:**

Basic use for setting up the instrument with all related parts, for surveying points. May be all you need, unless you need to go further or make adjustments. Assumes you'll use the PDA to record data.

#### ***Topcon GTS 230 Series hardware manual***

Assumes you're not using the PDA, and also provides information on the total station parts, including checks for accuracy and adjustments.

#### ***Topsurv Manual***

Covers the software that runs on the PDA. The GPS & Survey sections can be looked at for more details on setting up the survey, etc. The GPS section isn't relevant so skip to page 6-1 for the survey section. It covers some stuff this unit doesn't do, like scanning, that you can ignore. The last section is on using the GTS for leveling.

### **Setting the instrument position: Option 1: Occupying a benchmark.**

This is probably the most accurate method of re-surveying a site (See "Benchmarking and Accuracy" section). If you've positioned the instrument over a benchmark, we just need three settings established: (i) the height of the instrument; (ii) a backsight to establish direction in the coordinate system being used; and (iii) the coordinates of the benchmark.

1. Connect the Data Collector (FC-100) using the serial cable from the 9-pin port on the bottom right of the data collector to the circular 6-pin serial port on the DTS, and power it up.
2. Start TopSURV from the Windows desktop, and either select an existing job, or create a new job. If you're starting a new data collection to later download, you'll probably want to create a new job. Unless you know otherwise, use the default settings by pressing Finish when it appears at the top.
3. Create a benchmark point by going to **Edt > Points** and **Add**. You can either give the point a new number or go with the assigned (1). If desired, set a code; the pull-down will have no existing codes, but you can create one simply by going to the entry and typing a code (like "BENCHMARK" or "THALWEG" or something), then you'll have that code available later as a pull-down selection. Enter the N (northing) E (easting) & Z (elevation) for the benchmark. Ok out of this point, and close the Points dialog to get back to the main menu.
4. Use the **Srv** menu to get to **Occ/BS Setup**. Then select the Occ. Point you just created for the benchmark. Measure the HI (height of the instrument) in the same units (probably meters) of the coordinate system. Remember that you are surveying from the benchmark, so the height of the instrument (HI) is important. All NEZ readings will be in reference to the NEZ of the benchmark – the HI and rod height entries are used by the instrument or data collector to make this work. If you later backsight to this point, the rod will be positioned on the benchmark. You might want to see if the numbers make sense. Forgetting to enter the correct HI or rod height will create a serious blunder in Z values
5. Consider what kind of backsight source you have. The possibilities are:
  - b. You know the true azimuth to some observable feature. You're only likely going to have that if you use a compass (corrected to true azimuth with the known magnetic declination.) In this case, you'll use enter this in the *BS Azimuth* field (the button toggles with *BS Point*). Note that compasses are only accurate to about a degree.
  - c. You know the coordinates of distant features like mountaintops, tv broadcast towers, etc. – too far away to occupy with the rod & reflector. In this case, you'll use *BS Point* with *Measure dist to BS* unchecked (if doing multiple readings to check accuracy, you'll need to set its **Meas Type** to HA/VA, which you'll find in its settings.)
  - d. You know the coordinates of nearby features that you can occupy with the rod & reflector. You'll check *Measure dist to BS*, or for multiple readings set **Meas Type** to HA/VA/SD.
6. Use either *BS Azimuth* or *BS Point* (more likely) to set the horizontal circle to true azimuths. If you have multiple points, use these to verify accuracy.

**BS Azimuth option:** If you don't have a second benchmark to sight to, but you do have the azimuth of a visible feature to sight to (maybe established with a compass), toggle to BS Azimuth and enter the azimuth as DDD.MMSS (thus 206°34'08" is entered as 206.3408.) Use coordinate system azimuths, so if you're using a compass for this, you'll need to know the magnetic declination and the coordinate system declination to enter the correct value. Then use the button in the lower right to Measure the BS. Note the BSCircle will display the reading from the TS, while the azimuth will match the new setting.

*Recommendation:* Change the BS Circle to read the same as the BS Azimuth by using its menu to **Set to Az**, then transfer this to the total station with **HC Set**. This allows you to read azimuths directly, and it may make it easier to later re-establish the backsight.

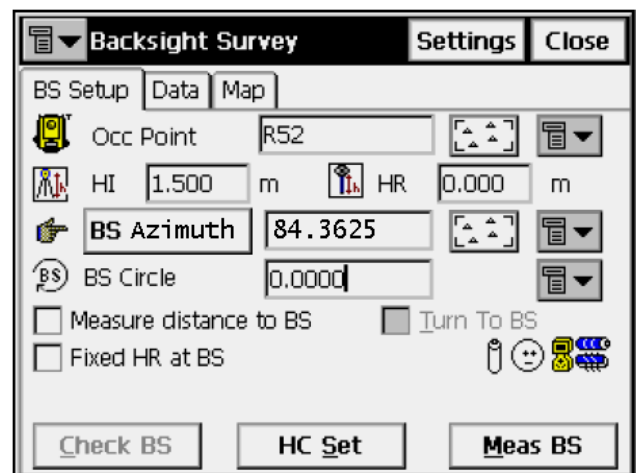
**Notes:**

- Remember that the instrument doesn't have a compass, but instead has a highly accurate horizontal circle, that reads from whichever direction it was pointing when you turn it on, from internal memory. The backsight establishes a true direction.
- The memory feature allows it to remember its sighting direction while at one location even if turned off and on. This is handy if something goes wrong and you need to start the software over again.
- *Recommendation:* Change the BS Circle to read the same as the BS Azimuth – Use the BS Circle menu to **Set to Az**, then transfer this to the total station with the **HC Set**. This allows you to read azimuths directly from the instrument display, and it may make it easier to later re-establish the backsight. If you haven't moved the instrument, you may be able to enter the reading shown on the instrument into BS Azimuth, then Meas to make that equal to the BS Circle. But the safest approach is to reshoot the backsight.
- You can sight to **multiple backsights** to determine accuracy and possibly re-sight individual backsights if you suspect an error.

**Problem with Using a Compass for Backsight**

Even if you adjust for magnetic declination, a compass will only be accurate to about a degree. The total station will then still be able to derive much more accurate angular readings, but they will all be off by the same amount as the compass reading was off. Your map will be accurate geometrically and it should look ok since its orientation to north should be as close as the compass gets you. But if you try to do a repeat survey later to measure change, using a compass to setup the backsight, those readings will all be off by the amount that new backsight was off. Thus the new survey will not align accurately with the old survey.

Alternative: Use *BS Point* with fixed points



**BS Point option:** If you have a point to sight to, use this option, even if you can't occupy it with the rod. You must have the point entered in the point list, so do this first if necessary using the method in step 3 above. Then measure to that point occupied with the rod, using its distance measurement, or to distant features that you can see but can't occupy (with *Measure dist to BS* unchecked, or for multiple readings set the **Meas Type** to HA/VA distance measurement). The instrument will derive the azimuth vector from the two N-E coordinates.

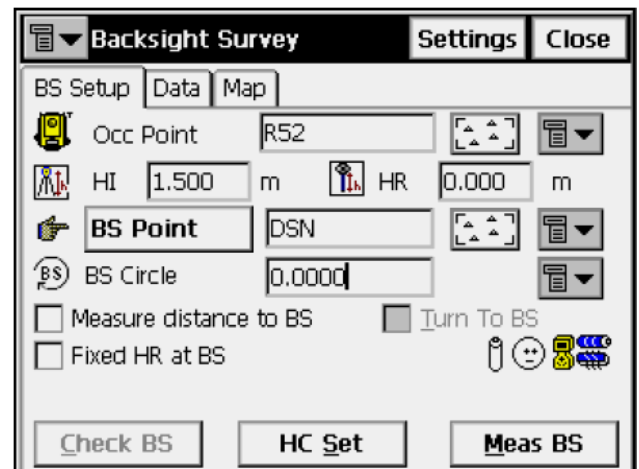
*Where do you get the coordinates for the backsight points?* One source might be from a GPS survey, though you may need to be concerned with limited accuracy. Submeter accuracy units can work for this, but even their accuracy is not as good as you can get with the total station. So think of distance as your friend. As seen in the Table 1 in the *Benchmarking and Accuracy* section, a GPS point accurate to 20 cm at 20 m distance has an angular accuracy of 2063" (that's 2063 seconds of arc, or 0.57°), so this would be better than a compass reading. With a GPS point accurate to 5 m, you would need to be at 500 m distance to see this angular accuracy; this is beyond a reasonable sighting ranges. Greater distances reach finer accuracies, though only survey-grade GPS readings to 0.01 m come close to the ~5" accuracy of the total station.

**Notes:**

- Remember that the instrument doesn't have a compass, but instead has a highly accurate horizontal circle, that reads from whichever direction it was pointing when you turn it on, from internal memory. The backsight establishes a true direction.
- The memory feature allows it to remember its sighting direction while at one location even if turned off and on. This is handy if something goes wrong and you need to start the software over again.
- *Recommendation:* Change the BS Circle to read the same as the BS Azimuth by using its menu to **Set to Az**, then transfer this to the total station with **HC Set**. This allows you to read azimuths directly from the instrument display, and it may make it easier to later re-establish the backsight. If you haven't moved the instrument, you may be able to enter the reading shown on the instrument into BS Azimuth, then **Meas** to make that equal to the BS Circle. But the safest approach is to reshoot the backsight.
- You can sight to **multiple backsights** to determine accuracy and possibly re-sight individual backsights if you suspect an error.

**Re-establishing an earlier survey's coordinate framework**

If you're happy enough with the original survey, and any compass-derived error isn't considered a problem, you can re-establish that framework later if you had established some fixed points – on permanent stable features or monumented with hammered-in rebar. If from your instrument location (which you will need to have monumented for the repeat survey) you can sight to a fairly distant stable feature, you can record that azimuth to use for a backsight when you return. You'll still have the original compass backsight error, but it is fixed so the surveys will overlay accurately. *So when you're planning a repeat survey, even this method should only be used to establish a coordinate system, and you'll need to monument it so you can derive repeatable coordinates which you can use for backsights.*



### **Setting the instrument position: Option 2: Resection to two or more benchmarks.**

Though a bit less accurate, this option has the advantage of a somewhat easier setup since the TS doesn't have to be positioned over the benchmark. You can however improve accuracy if you have more than two benchmarks to sight to. Note that there are two types of resection: one that only uses angles, requiring at least three benchmarks; the other using distance. We'll do the latter. The first few steps are same as with option 1 above.

1. Connect the Data Collector (FC-100) using the serial cable, and power it up.
2. Start TopSURV from the Windows desktop, and either select an existing job, or create a new job. If you're starting a new data collection to later download, you'll probably want to create a new job. Unless you know otherwise, use the default settings by pressing Finish when it appears at the top.
3. Use the **Srv** menu to get to **Resection**. You'll initially see a place to put an occupied point for the instrument, but you don't have this so go to **Next** to get to your first benchmark to sight to. *If you want your derived instrument location to be used later as a benchmark, you should enter an HI value, at the measured height of the instrument above the benchmark you've created; then your saved position will be of the benchmark location below the instrument, not the actual instrument.* Select the point from the list, enter the rod height, and press the **Meas** button once you've aimed the TS at the reflector. It should return with a happy sound. Repeat for the next benchmark, etc. Check the map to see how the points are arranged. Go to the Set tab to see how well the resection worked. You'll see values ('Sd' I think is standard deviation) indicating how close your readings are. You can re-measure readings to see if you can improve them; you can also remove a reading by going to remeasure and exiting (not closing) back to the Set.
4. When you're happy with the results, press the **Accept** button to set the instrument location. You'll be taken to the **Store Point** dialog, indicating that you want to store the instrument position. *Note that unless you had entered an HI value before, this position is that of the instrument itself – this works fine, unless you need to re-occupy that point as a benchmark later on.*

#### Notes:

- Resecting to 3 or more points will produce an error check, and you might use this to note problematic readings.
- If you are resecting, typically you are not at a permanent benchmark, so the HI (height of the instrument) isn't needed. The NEZ for the instrument point is at the Z for the instrument itself, not the ground beneath it. It's ok to enter an HI value, but make sure you use it for both resection and foresights. You might want to check the numbers you get to avoid blunders, especially in Z values.

### Capturing points

At this point, we'll assume that your instrument position is known and it has a backsight direction, from either of the above options. Now the instrument is ready to capture new points.

Use **Srv > Observations** to start capturing points. As with the point creation process, you have a minimal data dictionary to use. (Perhaps you can make this more elaborate, but the basic version works for me.) The **Point** is initially assigned a new number, but you can change this and even mix letters or other characters. If you start the id with a letter, the program will automatically use this as a prefix to increment (e.g., from 'A1' to 'A2', etc.). The **Code** is useful for categorizing your operations, and you can create new types on the fly: existing code types can be selected with a pull-down, or you can type in a new code, like "thalweg". One type of point you may need is the next instrument position, where you should also hammer in a benchmark. Note the rod height is easily seen and altered – you may need to change the rod height in the middle of the survey to make it easier to see over brush. To survey a point, sight it first, then press the **Meas** button. It will beep a happy sound if you get a good point, then will prompt you for the HR – you don't need to change this; this just allows you to make a change if you realize it's wrong. You will also be prompted for codes and such.

### Moving the instrument

While you should try to maximize the number of points measured from a given instrument setup, you will often find that you need to move the instrument to a new location. The most accurate way to do this is to: (1) start from a benchmarked location, using a measured and entered HI (height of the instrument); (2) survey in and establish the next position as a benchmark (either with a temporary or permanent stake); (3) move the instrument to the next position, measuring and entering its HI, and using the previous position as the backsight.

### Exporting Data & Bringing it into a computer

To export a text file of points, use **Job > Export ... To File ...**

In the To File dialog, specify **Data: Points, Format: Text** then **Next** to go to a dialog for specifying a name and location. (By default it goes into \CF Card\TPS TopSURV\IEFiles – but check this anyway.) Then in text file format, specify comma or tab delimited, etc.

You can see your file in the FC-100 by opening it in MS WordPad (to keep TopSURV running, press the windows button to get a start menu, and go to MS WordPad – when you exit it, you'll be back in TopSURV.)

There are several ways of getting the data into another computer. The simplest is just to plug the USB cable in, and set up Microsoft ActiveSync to use the connected device as a guest (partnerships seem unnecessary). Using the location noted for export files (probably \CF Card TPS TopSURV\IEFiles), explore for the text file you created. Open in Excel to convert the tab-delimited text. Remember that NEZ is essentially YXZ, not XYZ.

### **Exporting Raw Data:**

The above export gets 3d coordinates, and is useful if you were able to accurately set up the instrument on a known location, and were able to backsight accurately to a known point. If instead you have, say, GPS points that are approximately located but you are going to post-

process these for better accuracy, you wouldn't have been able to establish the coordinates in the field. You may have multiple options. It may be that you can use the Topcon software to make this conversion for you; you'll need to find out how. One option is to export all the raw data and do all of the conversions yourself in Excel; that's what I usually do. To export raw data, in the "To File" section of Export, select "Raw Data" and choose a format to go into. Some I've tried are TDS Raw Data (maybe the simplest), Field Book, LandXML.

### **Importing Data from another computer**

You can basically reverse the above process to import a file of coordinates. This is handy if you have known points you want to import, maybe from a GIS file. You will probably want to maintain the same fields. Use **Job > Import** to get to the right dialog.

## Benchmarking and Accuracy

Accurate surveys require good control points, especially if a study area is going to be revisited to determine change over time. This is commonly needed for riparian surveys, where floods can move stream channel features. To attain centimeter accuracy, benchmarks such as 4' rebar must be hammered into stable parts of the landscape. But how do we determine positions for these benchmarks?

**Local vs. Global Coordinate Systems.** Traditional land survey methods typically use a local coordinate system, and rely on benchmarks to maintain accuracy over time. These can be converted into global coordinates such as the Geographic Coordinate System (GCS) of latitude and longitude or cartesian coordinate systems based upon GCS such as UTM or state plane. Critical to these is the datum system used, such as WGS84; survey manuals may refer to these global coordinates as WGS84.

GPS provides global coordinates, but we must consider accuracy. If we have the time, situation and equipment to derive centimeter-accuracy survey-grade GPS coordinates, we have a good way to derive global coordinates for benchmarking. This is often not possible, so we're typically using submeter-accuracy GPS for benchmarking. The best accuracy for these is attained through post-processing. For the Trimble ProXH, we can probably get 20 cm or so accuracy, under good conditions (pretty clear sky view, right time).

**Position vs Angular Accuracy.** First we need to consider the kinds of accuracy benchmarking provides. There is both vertical (elevation) and horizontal (xy coordinates) accuracy, of course, but there is also both positional and angular accuracy. Positional accuracy is fairly simple – if you are off by some distance in x and y coordinates, that's your error.

*Angular accuracy* relates to position accuracy in two ways. (1) If a reading by the TS is off by a given angle, the surveyed position can be off by the sine of the angle times the distance. With a 5-second TS like the GTS235, the relative error this creates is rarely a concern, though the absolute angle depends on the backsight setting. (2) The positions of the *from* and *to* points used for backsighting to set the HC will influence the accuracy of the HC, and thus of the positions surveyed. Greater backsight distances are needed to reduce the effect of position errors on this angular setting; a simple rule of thumb is

$$B = \frac{P}{A} M$$

where: B = backsight distance (distance from the instrument to the backsight point)

P = backsight point accuracy

A = desired survey accuracy

M = maximum distance to surveyed point

So for a 50-m maximum survey distance, a 20-cm backsight point accuracy from a good GPS point, to get a 1 cm accuracy from angular settings requires  $50 * 0.2/0.01 = 1000$  m backsight distance. For 10 cm accuracy, that would be 100 m.

Note that this does not avoid the effect of *position accuracy* for the instrument; it only avoids errors resulting from the angular HC setting. If the instrument position is off by 0.2 m, after using a GPS to determine its position, then all of the points will be off by this much, in addition to any other errors. This points to the need to use benchmarks for surveys needing repeating. If a repeat survey depends on GPS to reestablish instrument position, the accuracy of the GPS reading limits the accuracy of the survey.

**Recommendations.**

1. So for surveys that are going to be repeated, benchmarks are going to be needed, unless GPS accuracy is sufficient for the changes expected.
2. To establish an correctly oriented coordinate system for mapping, GPS can be used for benchmarking instrument and backsight position, as long as the distance is sufficient to derive an accurate direction. Use the equation on the previous page to determine this, but compare this with the accuracy of a compass (typically around 1°, or 3600 sec), which can be improved upon with at least a 20 m backsight distance, given a 20-cm GPS accuracy:

**Table 1. Angular accuracy in seconds from sightings to GPS points from 0.01 to 5 m accuracy**

		Position accuracy from 0.01 to 5 m												
dist (m)	arc (m) from 1°	0.01	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	5	m
10	0.17	206	2063	4126	6189	8253	10318	12383	14450	16519	18589	20661	108000	sec
20	0.35	103	1031	2063	3094	4126	5157	6189	7221	8253	9285	10318	52119	"
30	0.52	69	688	1375	2063	2750	3438	4126	4813	5501	6189	6877	34539	"
40	0.70	52	516	1031	1547	2063	2578	3094	3610	4126	4641	5157	25851	"
50	0.87	41	413	825	1238	1650	2063	2475	2888	3300	3713	4126	20661	"
60	1.05	34	344	688	1031	1375	1719	2063	2406	2750	3094	3438	17209	"
70	1.22	29	295	589	884	1179	1473	1768	2063	2357	2652	2947	14746	"
80	1.40	26	258	516	773	1031	1289	1547	1805	2063	2321	2578	12900	"
90	1.57	23	229	458	688	917	1146	1375	1604	1833	2063	2292	11465	"
100	1.75	21	206	413	619	825	1031	1238	1444	1650	1856	2063	10318	"
200	3.49	10	103	206	309	413	516	619	722	825	928	1031	5157	"
300	5.24	7	69	138	206	275	344	413	481	550	619	688	3438	"
400	6.98	5	52	103	155	206	258	309	361	413	464	516	2578	"
500	8.73	4	41	83	124	165	206	248	289	330	371	413	2063	"
600	10.47	3	34	69	103	138	172	206	241	275	309	344	1719	"
700	12.22	3	29	59	88	118	147	177	206	236	265	295	1473	"
800	13.96	3	26	52	77	103	129	155	180	206	232	258	1289	"
900	15.71	2	23	46	69	92	115	138	160	183	206	229	1146	"
1000	17.45	2	21	41	62	83	103	124	144	165	186	206	1031	"