System 1200 Newsletter – No. 28
Resections

Resections With TPS1200

The last newsletter gave some background information into all the setup methods which are available with TPS1200.

This newsletter focuses on the **Resection** method and will cover the basics - the next newsletter will go into a much deeper level – so ensure to read and understand this newsletter first!

Resection – The Basics

A **Resection** (also sometimes called a **Free-Station**) allows the coordinates (easting, northing and height) and orientation of the TPS station to be determined by measuring to a number of known (target) points.

So this method is perfect to use where you need to have the freedom to set up the total station where it is most useful – the only restriction being that you must be able to see a number of target points. The coordinates of the target points can be known in position and height, position only or even height only (more on this later).

The coordinates of the total station are computed using a **least squares method**. Next week's newsletter will also introduce a method known as the robust method, but for now, only the least squares method will be discussed.

Introduction to Least Squares

Before looking at the resection application itself on the TPS1200 it is worthwhile to get a basic understanding of least squares using a simple example.

Least Squares – Simplest Case

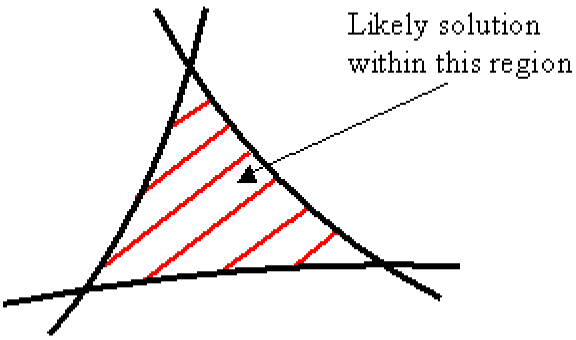
Imagine your total station can only measure distances – it cannot measure horizontal or vertical angles (it could be a DISTO on a tripod!). You need to determine the easting and northing coordinates of the location where you set up the total station.

You set up this total station in a location where you can measure a distance to 3 known target points. You now measure a distance to each of the 3 target points individually.

After measuring a distance to the first target point, you still do not know the coordinates of the total station. The location of the total station could be anywhere on a circle which has its centre at the measured target point and radius of the distance measured to the first target point.

After measuring the second target point the location of the total station is ambiguous – it could be at one of 2 locations where 2 circles intersect. But knowing where you are in relation to the 2 target points, you can choose the correct location – and you have now determined the coordinates of the total station.

But now measure the third target point – what does this mean? We now have "redundancy" – or put another way, we have more measurements than we need. This can be visualised as the intersection of 3 circles as shown below. But because the measurements will not be perfect (and probably, the coordinates of the target points are also not perfect) then circles will not perfectly intersect.



So how can we now decide where is the "correct" or even the "best" location of the total station? Is it exactly in the centre of the "curved" triangle? Is at one of the intersection points of 2 of the circles? The "correct" answer can never be known, but we can make a "best guess" using the method known as least squares.

But what does it mean to "use the method known as least squares"?

Imagine that we guess that the most likely location of the total station is somewhere near the centre of the triangle and compute the coordinates of the centre of the triangle. It is now possible to compute the distance from this "guess" to each of the target points (the "**computed**" distance). This distance will not be the same as the distances we originally measured (the "**observed**" distance).

Knowing the "**computed**" distance and the "**observed**" distance, it is possible to compute the difference between these 2 distances – the "**residual**". This can be repeated for each of the target points. We then know the residuals for each of the target points. We must now square each of these residuals and then add them together which gives us the sum of the squares of the residuals.

Putting it in the simplest terms, the least squares methods states that the most likely solution is the one where the sum of the squares of the residuals is minimised.

So we could now repeatedly choose different locations for our total station, calculate the "computed" distances, compute the residuals and compute the sum of the squares of the residuals. Eventually, we would find the location where the sum of the squares of the residuals is minimised and this would be the most likely solution (this is why this method is called the method of least squares). In reality this process is automated, but fundamentally remains the same - the aim is to find the solution where the sum of the squares of the residuals is minimised.

This process is used in the resection method.

Least Squares – Extend The Basic Idea

Now that the basic concept of least squares is understood, it is possible to extend this idea.

Imagine the more realistic problem of computing the easting, northing and height coordinates of the total station and the orientation using the resection method. Additionally, this time, the total station method has also measured horizontal and vertical angles, has measured distances to only some points and only the easting and northing coordinates of some target points are known – for others, only a height is known.

This problem is much more complex – there are many more measurements (both angular and distance) and there are more unknowns to solve (easting, northing, height and orientation) but the fundamental way of solving the problem is the same as before.

Bad Observations, Bad Data?

Imagine now that one of the measurements to the target points is wrong (maybe the wrong reflector type was chosen). To handle this, it must therefore be possible to identify and then remove this measurement from the computation so that the result (the coordinates of the total station) is not influenced by the "wrong" measurement. With the TPS1200 resection method, it is possible to disable individual measurements and re-compute the resection.

Or maybe the coordinates of the target point are wrong (or maybe the easting and northing is correct and the height is wrong). To handle this, it must be possible to use only the 2D position or height only coordinate of the target point – this is also possible using the TPS1200 resection method.

Solving For Scale

Imagine you need to complete a survey in an area which is surrounded by target points for which the coordinates are known. You are sure that the points are relatively homogeneous (that is, they fit together well), but you have no idea about how the points were established. Were they measured using GPS? Were they measured using TPS – if yes then what ppm value was used? Were they measured "on the ground" or "on the grid"?

For your survey, it actually does not matter how the target points were measured – it is only necessary that you can compute the coordinates of the total station which "fits" or "ties into" these points.

In order to do this, it is necessary to also compute the scale factor. This is basically another "unknown" – the coordinates and orientation of the total station are unknowns (it was already described how to compute these unknowns), the scale factor is simply an additional unknown. Once the scale factor is computed, this scale factor can also then be used when all subsequent measurements are made – thus the computed coordinates of the total station and all measurements "fit" with the control points.

The Resection Method On TPS1200

This section will now describe step by step how to use the resection method on the TPS1200.

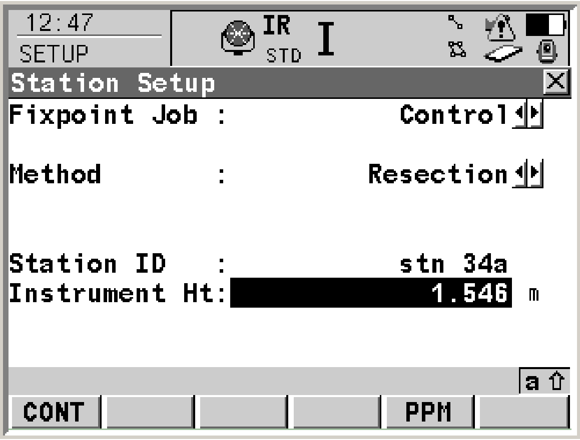
Choosing The Method

In the **SETUP Station Setup** panel, choose **Resection** at the **Method** prompt.

It is also necessary to choose the **Fixpoint** job (this is where the target points are stored), to enter the **Station ID** (what point ID should be given to station being computed) and the **Instrument Ht**.

The **F5(PPM)** button allows you to quickly access the **CONFIGURE TPS Corrections** panel if you need to check the current atmospheric or geometric corrections.

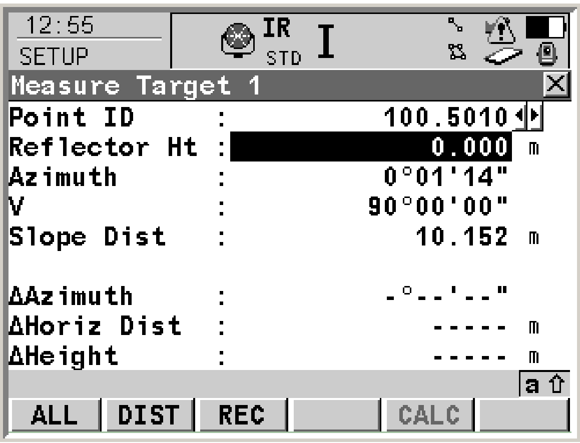
Resections



If you need to make changes to any configuration settings then press **shift F2(CONF)** to access the **SETUP Configuration** panel (the settings on this panel were described in last weeks newsletter). Press **F1(CONT)** to access the **SETUP Measure Target 1** panel.

MEASURING THE TARGET POINTS

Select the target point which is to be measured, aim the instrument at the point and measure the point.

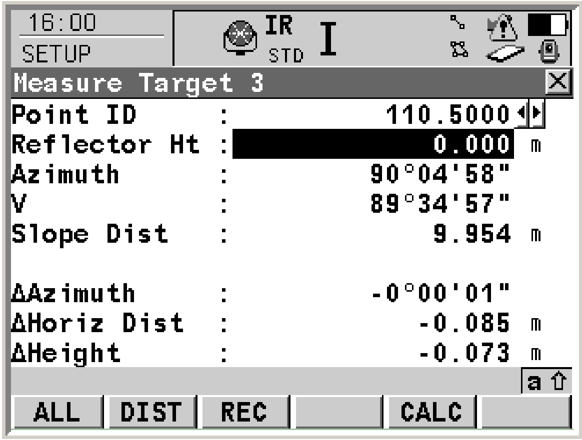


Once the point is stored, the **SETUP Measure Target 2** panel will appear (it is possible to measure up to 10 points).

Again, measure to this target point – once this point is stored it is possible to compute the coordinates of the station and hence the message line **Press CALC to display results** is shown.

In our example, we will measure one more target point. Since the coordinates of the station can now be computed, the instrument (if configured) will turn automatically to the next point.

To help you find the next target point more easily, you can press **shift F2(FIND)** to access the **SETUP Find Target** panel – which is similar to the normal stakeout panel. Alternatively you could press **shift F4(POSIT)** to turn the instrument to the point (this may be useful if you did not configure the instrument to automatically turn to the point).

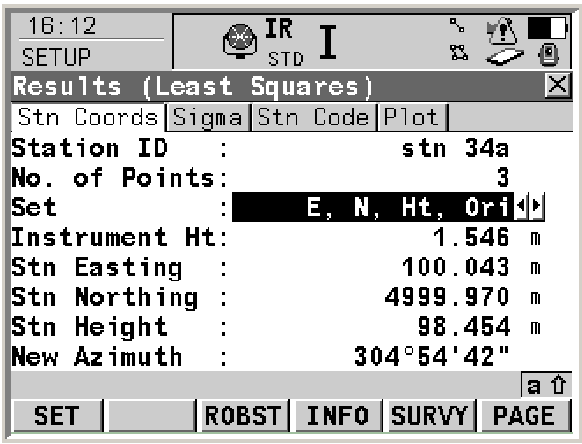


Once the instrument is aimed at target point 3, then it is possible to already get an indication of the quality of the resection by looking at the **ΔAzimuth**, **ΔHoriz Dist** and **ΔHeight** values.

Store the measurement and press **F5(CALC)** to access the **SETUP Results** panel. Note, you may now see some warning panels if the accuracy tolerances are exceeded (there are different messages for the positional calculation, height, orientation and scale calculations). If no solution is possible (you have probably measured to the wrong points) then another message would be shown.

THE RESULTS OF THE RESECTION

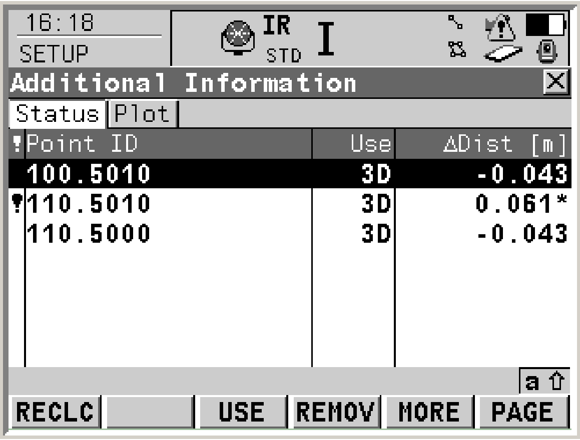
This panel contains 4 page views.



The **Stn Coords** page is straightforward and shows information about the computed station, how many points were measured etc. Here it is possible to decide what should be "set" at the **Set** prompt.

The **F3(ROBST)** button allows a "robust" solution to be computed – this will be explained in more detail in the next newsletter.

The **F4(INFO)** button accesses the **SETUP Additional Information** panel which allows the residuals relating to the individual measurements to be viewed – remember, the residuals are the computed values minus the observed values. The next newsletter will show that sometime the observation with the biggest residuals does not always mean there is a problem with that observation!

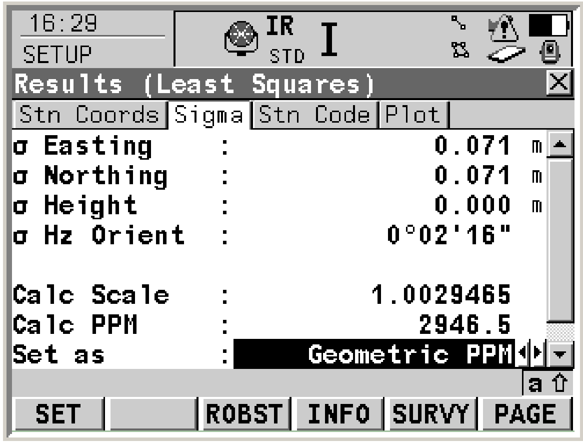


It is also possible here to decide if each observation should be used as a 3D, 2D or 1D observation or if the observation should be excluded from the calculation. More on this panel next week – but for now, press **F1(RECLC)** to recomputed the resection and return to the **SETUP Results** panel.

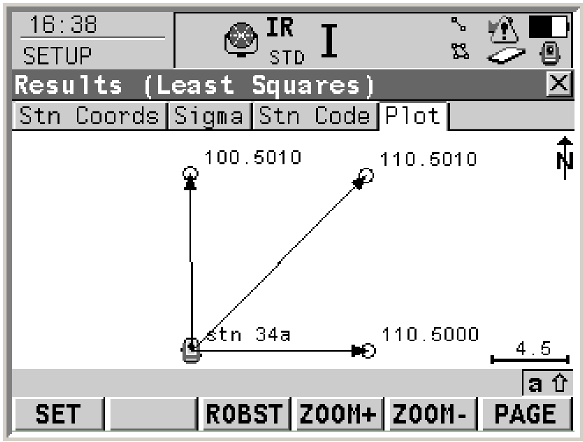
The **F5(SURVY)** button returns to the panels where you can measure the target points – you can either survey additional target points, or re-measure previously measured points (in this case, the measurement to the previously measured points is "over-written"). The **F5(SURVY)** button is the same as pressing **ESC**.

The **Sigma** page gives an indication to the quality of the computed solutions (the solutions in this case are the **Easting**, **Northing**, **Height** and **Orientation**). The sigma values are computed as part of the least squares method – the bigger the residuals of the observations (or the worse the accuracy of the coordinates of the control points) the higher the sigma values of the computed coordinates and orientation - more on this in the next newsletter.

Since we also chose to compute a scale, the result of the computed scales is shown (remember, we computed this in order to "fit" to the existing control points). The **Set as** prompt allows this computed ppm value to be "used" as the current **Geometric ppm**– this would make sense in most cases since we do want our survey to fit to the control points.



The **Stn Code** page allows a point code to be attached to the station and the **Plot** page gives a graphical plot of the results. The points used in the resection will be shown in black, all other points are grey.



Remember to use **shift F3(FIT)** to fit the plot to all points, use **shift F3(FIT R)** to fit the plot to the result of the resection.

Finally, **F1(SET)** stores the resection result to the database and sets the new coordinates and orientation of the total station.

SUMMARY

The next newsletter will go even more deeply into resections – be prepared!