Leica Geosystems

System 1200 Newsletter – No.9

Coordinates and Coordinate Conversions

System 1200 makes the passing of data between the TPS1200 and GPS1200 instruments simple and seamless.

For example, a typical topographic survey may mean using GPS1200 to survey points suitable for GPS surveying and then put the CF card into the TPS1200 to complete the survey. Or control points are surveyed with GPS1200 and then maybe these points are used as backsight points for a resection when using TPS1200.

But this of course is only possible with the conversion of the coordinates of the surveyed points. Since the mixing of TPS and GPS data is becoming more and more commonplace and will continue to do so in the future, it is worth to go "back to basics" and explain the fundamentals of coordinate conversions.

Three years ago a series of System500 newsletters focussed on coordinates and coordinate conversions – these newsletter was extremely popular and even experienced surveyors found them useful.

The next few newsletters will focus on the conversion of coordinates. Even if you are a "pure" TPS only or GPS only user it is strongly recommended to read these newsletters – it is highly likely that you will also start to combine the use of TPS and GPS instruments.

Storage of Points Within System 1200

The first and most important thing to remember with regards to the storing of points measured using the individual TPS1200 and GPS1200 instruments is the following:

Points measured with a **TPS1200** instrument are always stored with **Local Grid** coordinates in the DBX database.

Points measured with a **GPS1200** instrument are always stored with **WGS84 Geodetic** coordinates in the DBX database.

Note, the two terms local grid and WGS84 geodetic should be considered as **coordinate types** (this newsletter will later introduce 3 other coordinate types which are needed to convert between local grid and WGS84 geodetic).

It is only possible to convert between coordinate types if a **coordinate system** is being used. As described later, a coordinate system (typically) consists of a transformation, a local ellipsoid and a projection and should be thought of as the mathematical algorithms which allow the conversion between the two coordinate types.

Note, even during the conversion of the coordinates to other coordinate types, the original measured TPS points **always remain** stored as local grid within the DBX and the measured GPS points **always remain** stored as WGS84 geodetic within the DBX. The mathematical algorithms allow the other coordinate types to be computed and viewed, but the original stored coordinate remain the same.

Future newsletters will also discuss Onestep and Twostep coordinate systems, geoid models and CSCS models but for now, this newsletter will focus on the "classical" method of converting coordinates.

From GPS To TPS…

It is, of course, possible to convert coordinates in both directions - from TPS (local grid) to GPS (WGS84 geodetic) and in the other direction. Below it is described how coordinates are converted from GPS to TPS since ultimately, local most surveyors ultimately need their surveyed points to be exported with grid coordinates.

Step 1: WGS84 Geodetic To WGS84 Cartesian

As mentioned, a point surveyed with GPS1200 in the field is stored in the DBX as a WGS84 geodetic co-ordinate.

As with any geodetic coordinate, it is described in terms of **Latitude** (j), **Longitude**(l) and

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Height (**h**) above the ellipsoid (in this case the WGS84 ellipsoid).

To make the understanding of the coordinate conversion process a little simpler, we will consider how a point "evolves" as it goes through each stage of the coordinate conversion process to get to local grid. Our point **P** was surveyed with GPS1200 and has been stored in the DBX with the following WGS84 co-ordinates:

WGS84 latitude: 48°N

WGS84 longitude: 10°E

WGS84 ellipsoidal height: 500m

Knowing the **Ellipsoid** and using standard algorithms it is possible to compute the corresponding **Cartesian** co-ordinates for this same point (described in terms of **X**, **Y** and **Z**). Applying these algorithms to our point results in the following Cartesian co-ordinates:

WGS84 X: 4211089.525m

WGS84 Y: 742528.701m

WGS84 Z: 4717247.902m

Notice how much easier it is to imagine on the Earth where a point with geodetic co-ordinates is than Cartesian co-ordinates. Would you have known that the co-ordinates 4211089.525m, 742528.701m, 4717247.902m relate to a point on the ground near Heerbrugg in Switzerland?

So now it is clear we need an **ellipsoid** to convert between geodetic and Cartesian co-ordinate and back again.

However to get to local grid co-ordinates we firstly need to get to **Local Cartesian** co-ordinates.

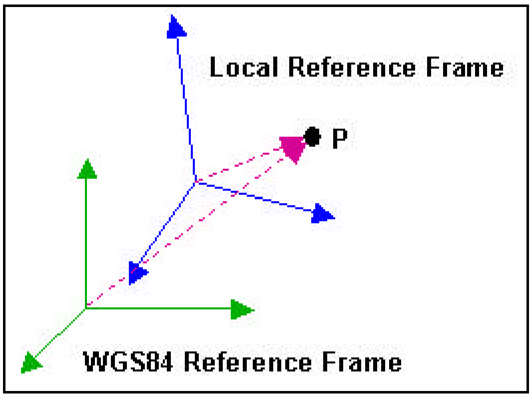
STEP 2: WGS84 CARTESIAN TO LOCAL CARTESIAN

To get from WGS84 Cartesian to local Cartesian coordinates a **transformation** is required. A transformation consists of up to **7 Parameters**. A full 7 Parameter Transformation consists of 3 **shifts** (dX, dY and dZ), **3 rotations** (Rx, Ry, Rz) and a **scale factor**. These parameters may already be known, or may need to be computed. In some cases, not all of these parameters are required

With the appropriate transformation parameters it is possible to use standard algorithms to convert between WGS84 Cartesian and local Cartesian co-ordinates.

But what really is the difference between local Cartesian co-ordinates and WGS84 Cartesian co-ordinates? They both describe the location of the same physical point in Cartesian coordinates, so why are the numbers different? It is because the origin, and/or the orientation of the two reference frames (the WGS84 and the local reference frames) are different. The transformation parameters actually mathematically describe the differences in the reference frames.

The diagram below shows two different reference frames with different origins and orientations.



In our example we will use a simple **3 Parameter Transformation** where **dX=100**, **dY=-200** and **dZ=300**. This results in local Cartesian co-ordinates of:

Local X: 4211189.525m

Local Y: 742328.701m

Local Z: 4717547.902m

STEP 3: LOCAL CARTESIAN TO LOCAL GEODETIC

As described earlier, an ellipsoid is needed to convert between Cartesian and geodetic co-ordinates. Because we are now converting "on the local side" – that is, converting coordinates between local Cartesian and local geodetic, this can be called the "**Local Ellipsoid**".

In this example we will use the **Bessel** ellipsoid. Using exactly the same algorithms as in Step 1 (but with a different ellipsoid) we can compute local geodetic co-ordinates. In our example we obtain the local geodetic co-ordinates:

Local latitude: 48° 00' 0.82316"N

Local longitude: 9° 59'49.66165"E

Local ellipsoidal ht: 1468.783m

Note, the local ellipsoid will is different for different countries – for example, Switzerland uses the Bessel ellipsoid and the British Isles uses the Airy ellipsoid. Some countries – USA and Australia for example actually use the WGS84 ellipsoid as the local ellipsoid.

Step 4: Local Geodetic to Local Grid

The final step in the coordinate conversion process is to compute grid coordinates – to do this we need a **Projection**.

Hundreds of projections exist, all of them are used to convert **Geodetic** co-ordinates (on a curved surface) to **Grid** co-ordinates (on a plane surface).

As for the local ellipsoid, the projection which is used for a specific country is the one which fits best to the shape of the country with the minimum of distortion. For example a Transverse Mercator projection is suitable for a country, which is long and thin in a north-south direction whereas a Lambert projection may better suit a more "square" shaped country. Some larger countries or States within the US will even use more than one projection to cover the country.

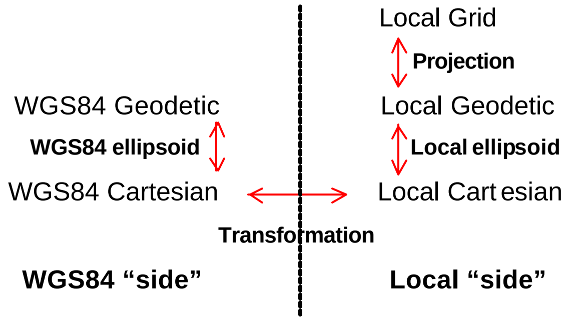
In our example we use the **Universal Transverse Mercator 32** and standard algorithms to obtain the following grid co-ordinates:

Easting: 790830.175m

Northing: 319665.347m

Ellipsoidal ht: 1486.783m

Now we have completed the conversion of the co-ordinates of our point from WGS84 geodetic co-ordinates to local grid with the following coordinate types:



Remember

Most important to remember is that points measured with a **TPS1200** instrument are always stored with **Local Grid** coordinates and points measured with a **GPS1200** instrument are always stored with **WGS84 Geodetic** co-ordinates in the DBX database. This never changes – using a coordinate system simply allows the coordinates to be converted, but the points themselves are not "re-stored".

Generally speaking, a coordinate system consists of several "elements"– the **Transformation**, the **Local Ellipsoid** and the **Projection** and it is these individual elements which allow the coordinate conversions to be made.

Future newsletters will explain in more detail the actual different coordinate system types – the Classic 3D, the Onestep and Twostep and will also explain the use of CSCS (country specific coordinate system) models and geoid models.