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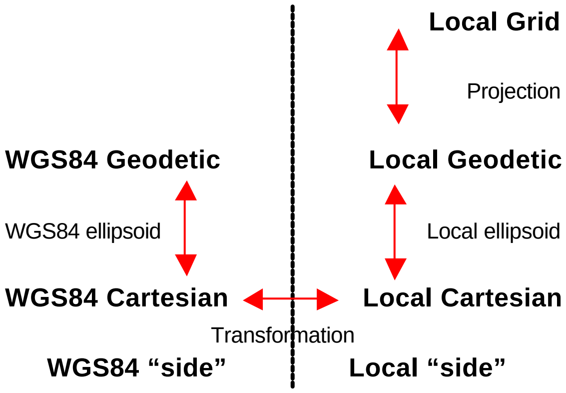
THE DIFFERENT TRANSFORMATION TYPES

Last week's newsletter described how coordinates can be converted between WGS84 co-ordinates and local grid coordinates.

This conversion process was summarised with the diagram below – remind yourself of the different steps and coordinate types.



Within LGO and System1200, this combination of transformation, local ellipsoid and projection is known as a **Classic 3D** coordinate system. It is clear that the local ellipsoid and projection must be known in order to use a Classic 3D coordinate system. If the transformation is not known and must be determined, then it is necessary that all common points used to determine the transformation must be known in position and height.

But what if you do not know the local ellipsoid and projection? Maybe you need to use GPS to survey an area which uses a completely arbitrary coordinate system - is it still possible to use GPS to complete this survey? Or what if the common points being used to determine the transformation are not known in position and height, but only position or height?

In these cases, it would be necessary to compute and use a **OneStep** transformation.

Regardless of which transformation type is used, the basic idea of matching common points – that is, matching the control points on the ground for which the grid coordinates are known and which have been measured with GPS - is the same.

Following the same theme as last week's newsletter, which described what happens "behind the scenes" when converting coordinates using a Classic 3D transformation, this newsletter describes the process of converting coordinates when using a OneStep coordinate system.

Next week's newsletters will describe the theory of the TwoStep transformation. Then finally, a future newsletter will bring all this theory to life with some real support cases and give tips as to when which transformation should be used and what should be considered when using the different transformation types.

THE ONESTEP COORDINATE SYSTEM

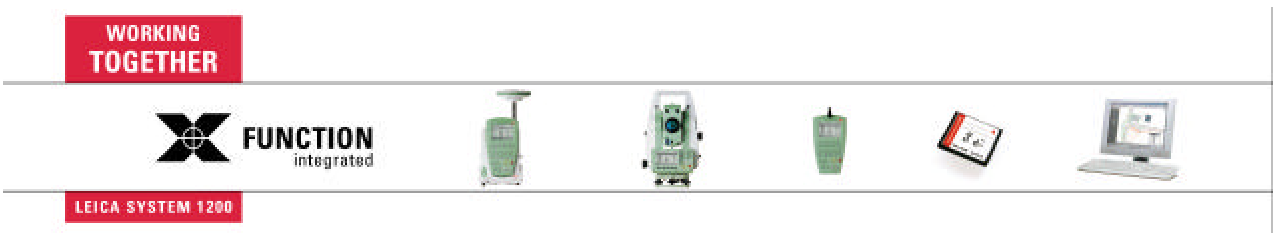
Imagine you want to use GPS to survey a quarry. For years, the quarry has been measured with TPS where the origin of this "grid system" is a survey marker in the corner of a field with the coordinates 1000, 5000 with additional control points positioned around the quarry.

These control points have been here for some years, they fit together "pretty good" and are of sufficient accuracy for regular surveys of the quarry. Clearly, in order to use GPS to survey this quarry we need GPS to fit into this grid system and give the same coordinates for points as if they had been measured with TPS.

The Classical 3D approach cannot be used here – there is no local ellipsoid and projection – simply an arbitrary grid!

The **OneStep** transformation is ideal for this situation. Remember, the ultimate goal of all coordinate systems is to convert coordinates between WGS84 geodetic and grid coordinates.

In order to do this with the OneStep coordinate system, the **position** and **height** components of this transformation are treated separately.



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HOW IT WORKS – POSITION COMPONENT

Imagine you have now measured all the control points with GPS in the area in which you wish to work and therefore know the coordinates of the common points in both WGS84 geodetic coordinates (the GPS measured points) and local grid coordinates (the easting and northing of the control points).

It is now possible to match these common points and compute the position component. Note, when matching points in order to compute the OneStep transformation it is possible to match points by position only – so even if the height of a control point is not known, the control point can still be used, with only the easting and northing of the point being used.

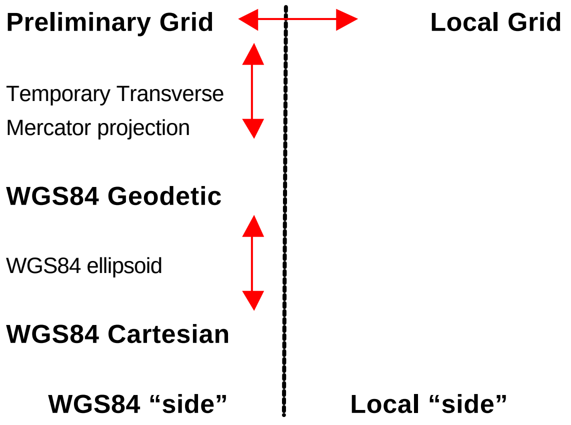
The position component of the OneStep coordinate system can be thought of as being computed in 2 steps (these 2 steps are “invisible” to the user).

The first step is that the WGS84 geodetic co-ordinates of the points are converted to grid coordinates using a “temporary” Transverse Mercator projection. The central meridian of this projection passes through the centre of gravity of the common points. This results in **preliminary grid co-ordinates** for the GPS measured points. These preliminary grid co-ordinates are never seen on System1200 or in LGO (they are of no interest to a user).

The second step is to match these **preliminary grid co-ordinates** with the **local grid control points** and compute the “best-fitting” **easting** and **northing shifts**, **rotation** and **scale factor** between these two sets of points. The positional component of the transformation is now computed. What this means is that the GPS coordinates are “squeezed” to fit into the local grid coordinates.

Note, it is possible to compute the positional component with only one common point being matched. In this case, the rotation is zero (grid north will point in the same direction as WGS84 north) and the scale is 1.

The conversion process as described last week is now modified as shown below.



Note that different to the Classic 3D transformation, there are no local geodetic or local Cartesian computed.

So now we have the position component of the OneStep transformation (this is actually nothing more than a 2D Helmert transformation).

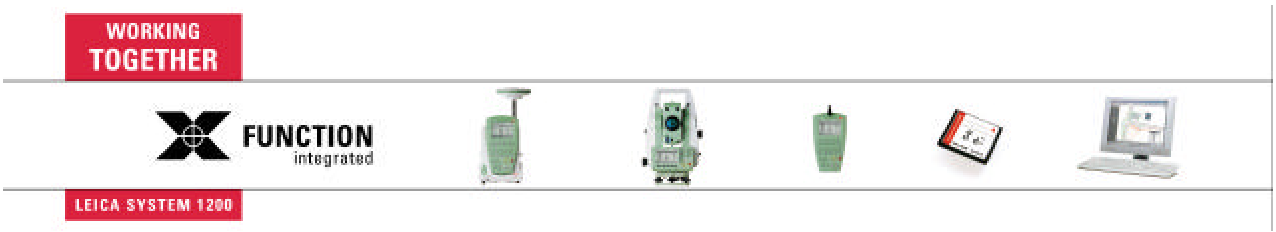
HOW IT WORKS – HEIGHT COMPONENT

Now we need to compute the height component of the OneStep transformation. Again, the common points have been matched and so the height component can be computed.

Similar to the way that points could be matched in position only, it is also possible to match points by height only. It is even possible to compute a OneStep transformation without knowing the height of any of the control points (in this case the height of the computed local points have the same height as the WGS84 coordinates).

If only one point is matched in height, then the WGS84 heights are simply shifted to fit to that one local height control point.

If **two** or **three** points are matched in height then a plane is fitted to these points. If **three** or more points are matched in height, a best fitting tilted plane is computed to approximate the local heights.



Leica Geosystems

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What Does All This Really Mean?

So now you know the theory of the OneStep transformation, but what really happens when you then attach this coordinate system to a job and survey the quarry with GPS? Basically GPS measured coordinates now "fit" to the real world – where the real world in this case is the existing quarry grid system.

In our quarry, the control points of course do not fit perfectly together – this can be seen when examining the residuals of the matched points during the determination of the coordinate system and is graphically shown below for position.

It could be said that the accuracy of GPS is actually "too good" for the quarry! But the aim was to retain the original TPS grid system (including any errors) such that when any point is now measured with GPS it would give the same coordinates as if it had been measured with TPS. This is now the case.

So the OneStep transformation sounds wonderful! It can be used when the local ellipsoid and projection is not known and can be used with control points where only the positions or heights of the points are known. Why is it not used everywhere for every survey?

There is of course a limit. The main disadvantage of the OneStep transformation is that it is limited to areas of about 10km square. This is because the WGS84 geodetic coordinates are projected to the "preliminary" grid co-ordinates using a Transverse Mercator projection with a scale of 1 with the central meridian passing through the centre of gravity of the common points. It is extremely unlikely that the control points in the grid system were also originally surveyed using the same scale factor which results from the OneStep Transverse Mercator. Differences will therefore quickly grow the further you are away from the centre of the common points.

How big can the errors grow if the area is extended? This is very hard to answer and mainly depends on how quickly (also if) the scale factor of the local points change within the area. Errors may sometimes quickly reach several centimetres. This question will be looked at in more detail in a future newsletter.

Remember

A OneStep transformation can be computed even when the local ellipsoid or projection is not known. Common points can be matched in position and height, in position only or even in height only.

The OneStep transformation treats the heights and position components of points separately.

There is a limit over the area in which a OneStep transformation can be used – this is due to the distortions resulting from scale errors. The errors increase depending on the distance from the centre of the common points.