

# Tutorial



# Georeferencing



with  
**TNTmips®**  
and TNTedit™

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# Before Getting Started

This tutorial introduces techniques for adding geographic control to your project materials. You will use this Georeference process to define the spatial position and coordinate reference system of your geodata objects. The TNT products automatically relate georeferenced objects to each other when they are displayed, measured, combined, and processed. Accurate georeferencing is an important step in preparing your geospatial materials for further use in the TNT products.

**Prerequisite Skills** This booklet assumes that you have completed the exercises in the tutorial booklets *Displaying Geospatial Data*, *TNT Product Concepts*, and *Coordinate Reference Systems*. Those exercises introduce essential skills and basic techniques that are not covered again here. Please consult those booklets and other TNT reference materials (installed or on MicroImages' web site) for any review you need.

**Sample Data** The exercises presented in this booklet use sample data that is distributed with the TNT products. If you do not have access to a TNT products DVD, you can download the data from MicroImages' web site. In particular, this booklet uses sample files in the GEOREF and CB\_DATA data collections. Make a read-write copy of those files on your hard drive; you may encounter problems if you work directly with the sample data on the DVD.

**More Documentation** This booklet is intended only as an introduction to georeferencing geospatial data. A number of Technical Guides (installed and on MicroImages' web site) provide further details and examples of georeferencing operations.

**TNTmips® Pro and TNTmips Free** TNTmips (the Map and Image Processing System) comes in three versions: the professional version of TNTmips (TNTmips Pro), the low-cost TNTmips Basic version, and the TNTmips Free version. All versions run exactly the same code from the TNT products DVD and have nearly the same features. If you did not purchase the professional version (which requires a software license key) or TNTmips Basic, then TNTmips operates in TNTmips Free mode. All the exercises can be completed in TNTmips Free using the sample geodata provided.

Randall B. Smith, Ph.D., 5 January 2012

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You can print or read this booklet in color from MicroImages' Web site. The Web site is also your source for the newest tutorial booklets on other topics. You can download an installation guide, sample data, and the latest version of TNTmips.

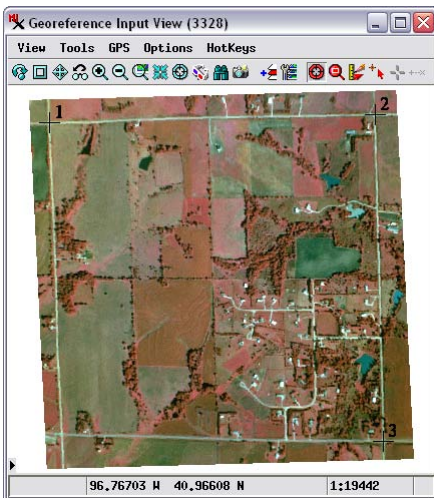
<http://www.microimages.com>

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# Starting Georeference

The Georeference process lets you create, edit, and store control information that relates the positions of raster cells and geometric elements in your spatial objects to map coordinates in a specified coordinate reference system. Accurate georeferencing allows you to overlay a spatial object correctly with all your other project materials.

In our first series of exercises you will work with a scanned color-infrared aerial photograph to add to and improve its georeference. This raster object illustrates one of the most common types of georeference information, *control point georeference*. Control points are locations within the spatial object where map coordinates in some coordinate reference system have been determined and stored. Control points are most often determined visually from other georeferenced data (the *reference object*). They are thus usually at locations that can be recognized in both the input and reference objects. To get us started, our scanned photograph has been provided with three control points in the centers of road intersections near the corners of the image.



## STEPS

- choose Main / Georeference from the TNTmips menu
- in the Georeference window, press the Open icon button (or choose File / Open) 
- select SEC32COMP from the SEC32G Project File

TNTmips stores georeference control information in a georeference subobject for each spatial object.

The exercises on pages 3-5 introduce the Georeference process interface and the use of reference objects. Exercises on pages 6-10 show you how to position and add control points using simple graphical tools. Concepts of residuals and residual models are discussed on pages 11 and 12. Exercises on pages 13-15 show you how to select, delete, and edit control points. Additional topics and advanced features are discussed on pages 15-19.

The spatial object you select for georeferencing is automatically displayed in the Georeference Input View. The input raster for this series of exercises has been provided with three control points, shown by the numbered cross symbols.

# The Control Point List

The Georeference window is the control and information center for the Georeference process. To start with we will focus on the center part of this window, which shows a list of the current control points with columns listing coordinates and other information for each point.

Each control point is assigned a number in the ID column; this ID is also shown in the Input View next to the point's symbol. Each control point also has a pair of *object coordinates* that define its position using the internal coordinates native to the object. Since we are working with a raster object, the object coordinates in this case are the fractional column and row positions within the raster, and the object coordinate columns are thus labeled Column and Row. (If we were georeferencing a geometric object, these columns would be labeled Object X and Object Y.) Each point also has a pair of *map coordinates* that define the point's location in the specified coordinate reference system (CRS). Our sample raster object is georeferenced to the NAD83 / UTM zone 14N CRS (as shown above the point list) in which map coordinates are expressed as Easting and Northing (in meters). These primary reference coordinate fields are therefore named Easting and Northing.

To the right of the primary CRS fields is a pair of fields that show map coordinates in an alternative secondary CRS, which defaults to a geographic (latitude/longitude) coordinate system using the same datum as the primary CRS. (In this example the datum is NAD83.) The secondary CRS columns in this case thus have headings Longitude and Latitude.

Object Coordinates
Map Coordinates  
(Primary CRS)
Map Coordinates  
(Secondary CRS)

| ID | Column | Row    | Easting    | Northing    | Longitude   | Latitude    | Residual (c) |
|----|--------|--------|------------|-------------|-------------|-------------|--------------|
| 1  | 28.55  | 35.43  | 687050.713 | 4538165.406 | 96.776873 W | 40.973230 N | 0.00         |
| 2  | 505.75 | 36.67  | 688659.088 | 4538204.756 | 96.757759 W | 40.973214 N | 0.00         |
| 3  | 494.80 | 525.14 | 688699.611 | 4536593.916 | 96.757769 W | 40.958704 N | 0.00         |

You can change the CRS used for the secondary map coordinate columns by choosing Secondary CRS from the Georeference window's Options menu.

Objects Statistics Formulas

3 Control Points  
 Cell Size (meters): X = 3.3712 Y = 3.2995  
 Projection Angle: 1.5464 Shear Angle: 1.2076 North Angle: 3.0107  
 RMS Residual (cells): X = 0.00 Y = 0.00 XY = 0.00  
 Mean Absolute Residual (cells): X = 0.00 Y = 0.00

## Choose a Reference Object

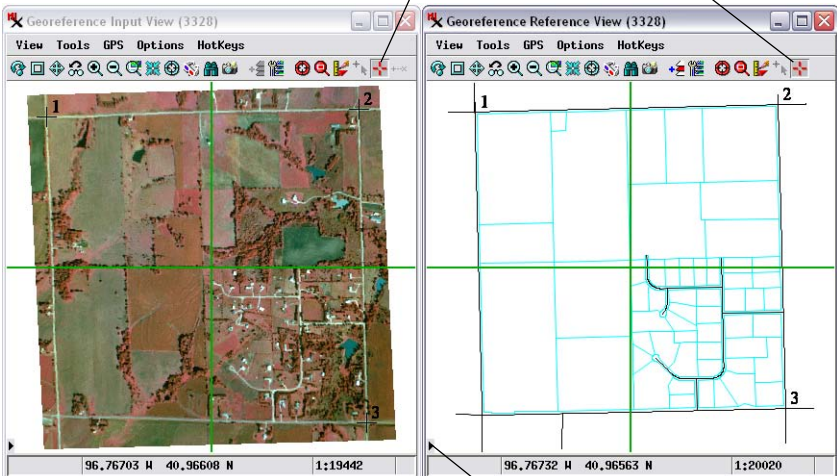
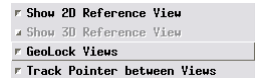
To improve the georeference for this aerial image we need to add more control points. You can use any type of accurately-georeferenced spatial object as a reference object. Here we open a separate Georeference Reference View and add a vector object as reference. This vector shows road centerlines as black lines and property boundaries in cyan. In the portions of the scene that are occupied by agricultural fields, many of the property boundary lines coincide with vegetated fence lines that are visible in the aerial image.

When you open an object that has existing georeference, as in this example, the Georeference window's default mode allows you to view control points and edit their locations (more about editing later). Press the Add Control Points icon button to change modes to enable adding new points. When you do so, the Crosshair tool is activated in both the Input and Reference views, and a crosshair appears centered in each view.

When you turn on Add Control Points mode, the Crosshair tool is automatically activated in the Input View and Reference View.

### STEPS

- from the Options menu on the Georeference window choose Show 2D Reference View
- on the Reference View, press the Add Layer icon button and select Quick-Add from the menu
- select SEC32VEC from the SEC32G Project File
- on the Georeference window's toolbar press the Add Control Points icon button
- open the Georeference window's Options menu and make sure that the Geolock Views setting is toggled on



NOTE: View windows open with a sidebar that can show a legend, locator, and magnifier. You can turn a view sidebar on and off using the Show/Hide Sidebar icon button. The views above are shown with the sidebars turned off to conserve space.

# The Crosshair Tool

## STEPS

- ☑ left-click on the titlebar of the Input View
- ☑ move the cursor in the Input View to the road intersection near the lower left corner of the image
- ☑ press **3** on your keyboard to zoom in to that location in both views
- ☑ in the Input View left-click at the center of the intersection to move the crosshair to that location
- ☑ use the arrow keys on your keyboard to adjust the crosshair position if necessary

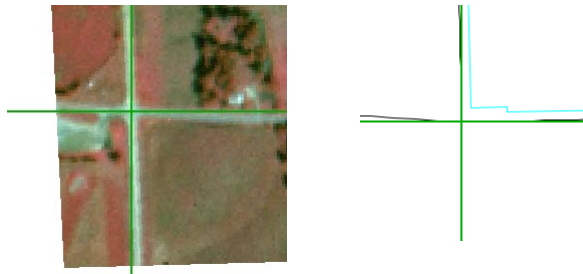
```
HotKeys
<space> Recenter at cursor
\ Redraw
0 Zoom to full view
1 Set zoom to 1X (raster)
2 Set zoom to 2X (raster)
3 Set zoom to 3X (raster)
4 Set zoom to 4X (raster)
+ Zoom in
- Zoom out
<arrows> Scroll 90 percent
```

Keyboard HotKeys can be used for zooming and panning either view at the cursor location without deactivating the crosshair tool.

You use the crosshair tool to indicate corresponding control point positions in the Input View and the Reference View. You can move the crosshair tool in several ways. You can left-click in the view to snap the crosshair intersection to that location. You can also drag the crosshair intersection to the desired location. The arrow keys on your keyboard are useful for making fine adjustments in the crosshair locations. When you move the cursor near one of the crosshair lines (but not near their intersection) the cursor changes from a cross to a double-arrow shape, allowing you to rotate the crosshairs to align with linear features in the view.

If you use the Zoom Box or Reposition tool in either view, remember to press the Corresponder tool icon button afterward to reactivate this tool. Instead of switching tools, you can use keystroke equivalents to zoom and pan. You can see a list of available keystroke actions using the Hotkey button on either view. A view must be the active window in order for you to use hotkeys for zooming at the cursor location.

The Geolock Views feature (on the Georef window's Options menu) is turned on by default, so that zooming or panning one view automatically causes the equivalent action in the other view (if enough control points exist to determine corresponding locations).

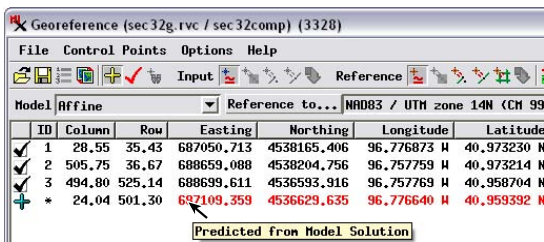


Crosshair positioned at the lower left road intersection in the Input View (left) and Reference View (right).



## Estimate from Model

When you are adding points, the control point list automatically includes an entry for the next point to be added (shown with an \* in the ID column). Note that when you placed the crosshair in the Input View, the Reference View crosshair also changed position, and map coordinates appeared in red in the Easting, Northing, Longitude, and Latitude fields in the listing for this point. If you place the mouse cursor over this listing, a DataTip informs you that these coordinates were “Predicted from Model Solution”.

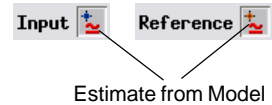


| ID  | Column | Row    | Easting     | Northing    | Longitude   | Latitude    |
|-----|--------|--------|-------------|-------------|-------------|-------------|
| 1   | 28.55  | 35.43  | 687050.713  | 4538165.406 | 96.776873 W | 40.973230 N |
| 2   | 505.75 | 36.67  | 688659.088  | 4538204.756 | 96.757759 W | 40.973214 N |
| 3   | 494.80 | 525.14 | 688699.611  | 4536593.916 | 96.757769 W | 40.958704 N |
| * 4 | 24.04  | 501.30 | 6872109.359 | 4536629.635 | 96.776640 W | 40.959392 N |

This behavior is the result when the Estimate from Model icon button is turned on in the Reference section of the Georeference window’s toolbar (the default condition). When the new point is initially placed in the Input View, the reference coordinates are automatically estimated based on the previously-placed points. When the same button is also turned on for the Input View (also the default state), input coordinates are estimated automatically if you first place the new point manually in the Reference View. (Note that further adjustments of the point position in either view do not trigger the estimation procedure.) This is a convenience feature; you should always manually adjust the “estimated” position to provide the best visual match between input and reference positions.

When you have moved the crosshair tool to the corresponding positions in both Input and Reference views, you add the new control point by pressing the Apply icon button on the Georeference window or by simply right-clicking with the mouse.

Several “helper” modes to assist in placing control points are selected using icon buttons in the Input and Reference toolbars on the Georeference window. The default mode for both is Estimate from Model.





### STEPS

- note the estimated map coordinates for the new point in the control point list
- in the Reference View drag the crosshair intersection to the road-line intersection
- when both crosshairs are in corresponding locations, press the Apply icon button on the Georeference window to add the control point



# Snap to Reference Elements

## STEPS

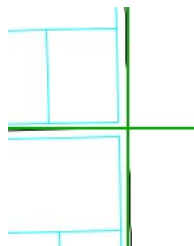
- zoom the views to full extents 
- in the active view, position the cursor near the road intersection north of control point 3 and press **2** to zoom in
- in the Reference group in the Georeference window's toolbar, turn on the Snap to End or Point icon 




- position the Input crosshair on the road intersection



- note that the crosshair in the Reference view has snapped to the exact intersection of the two black road lines

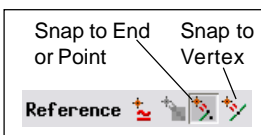


- add the control point 

When you are using a geometric object as the reference, two other Reference modes are useful: Snap to End or Point, and Snap to Vertex. When the input crosshair is moved in either view in these modes, the reference crosshair snaps to the relevant vector feature nearest the estimated position.

The Snap to End or Point mode snaps the crosshair to the nearest point element or to the nearest end of a line element, which can include the intersection of two or more lines. Thus this mode is useful when you are using road intersections in a geometric object as reference locations, as in this exercise.

The Snap to Vertex mode snaps the crosshair to the nearest vertex in the nearest geometric element in the reference object. Vertex locations are usually only evident where there is a pronounced corner in a line element or polygon boundary, as in the right-angle corners of many property boundaries in our reference object.



Snapped coordinates are also indicated in color in the control point list and by a DataTip.



| ID   | Column            | Row    | Easting    | Northing    | Longitude   | Latitude    | Residual (c) |
|--|-------------------|--------|------------|-------------|-------------|-------------|--------------|
| ✓ 1  | 28.55             | 35.43  | 687050.713 | 4538165.406 | 96.776873 W | 40.973230 N | 5.83         |
| ✓ 2  | 505.75            | 36.67  | 688659.088 | 4538204.756 | 96.757759 W | 40.973214 N | 6.25         |
| ✓ 3  | 494.80            | 525.14 | 686639.611 | 4536593.916 | 96.757769 W | 40.958704 N | 4.12         |
| ✓ 4  | 24.35             | 501.64 | 687089.011 | 4536593.215 | 96.776903 W | 40.958763 N | 5.90         |
| ✓ 5  | 498.01            | 370.81 | 686687.270 | 4537107.237 | 96.757759 W | 40.963328 N | 2.21         |
| +  | * [-----] [-----] |        |            |             |             |             |              |
| Predicted from Model Solution? Snapped to Nearest End or Point |                   |        |            |             |             |             |              |



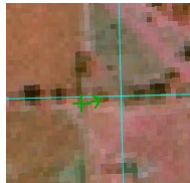
## Overlay Mode and the Tie Point Tool

If the input object you are georeferencing has at least three control points, you can add a reference object to the Input View as an overlay. Using an overlay is very useful when the reference is a geometric object (vector, CAD, or shape). Using a geometric overlay allows you to visually compare the registration of features in the input and reference in any area, not just at the control point locations.

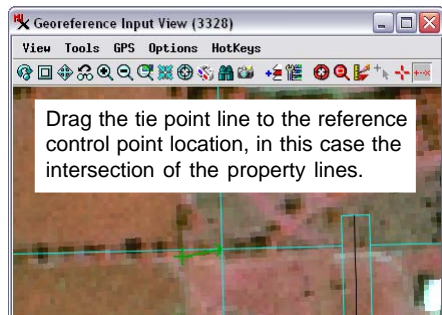
The Tie Point tool is provided for creating and editing control points when you have a reference overlay. With the Tie Point tool active, you drag with the mouse to create an elastic line in the Input View. The start of the line is marked with a cross symbol (+), which corresponds to the control point position in the *input* object. The end of the Tie Point line is marked by an arrowhead symbol (>), which denotes the control point position in the *reference* object.

**IMPORTANT:** always drag the Tie Point tool FROM the input object location TO the reference object location.




Start dragging the tie point line at the control point location in the input object.



After you have drawn the tie point line, you can adjust the position of either end of the line by dragging the end marker with the mouse. When the Snap to End or Point mode is active for the reference, you can drag the line close to the desired reference line end or point, and the Tie Point tool's reference end snaps to that feature.





### STEPS

- zoom the Input View to full extents
- press the Add Layer icon button  on the Input View and select Quick-Add from the menu
- select SEC32VEC from the SEC32G Project File
- zoom the Input View in to center of the image, near which two fence lines intersect at right angles
- turn on the Tie Point tool  on the Input View
- position the mouse on the fence intersection in the input image
- left-click and drag the '>' end of the tie point line to the property line intersection in the reference vector
- release the mouse button
- add the control point 

# Using a Reference Raster

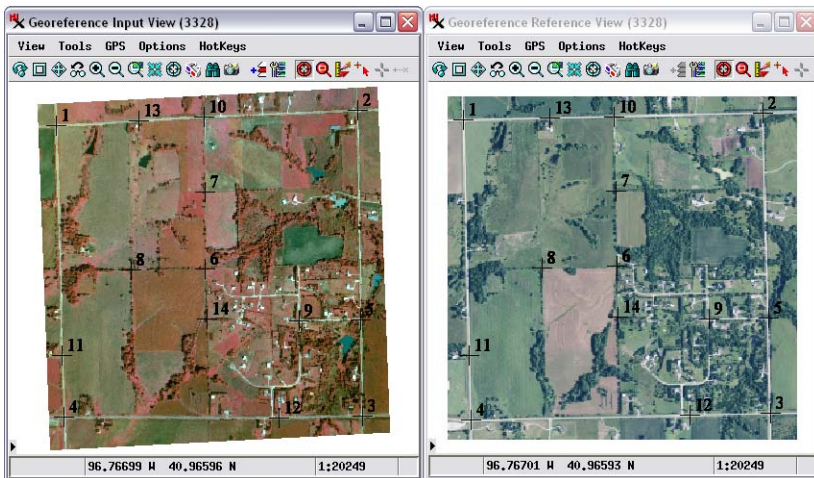
## STEPS

- press the Layer Manager icon  button in the Input View
- in the Layer Manager, right-click on the listing for the vector layer and choose Remove Layer from the menu (you can do this instead in the sidebar legend if open)
- repeat for the Reference View
- on the Reference View, press the Add Layer icon button  and select SEC32G.RVC / SEC32ORTHO
- turn on the Crosshair tool in either view
- add some more new control points at road and fence line junctions, with a goal of a relatively even distribution of points

You should now have five control points near the edges of the input image and one near the center. We can find additional control point locations using an image as a reference. The new reference we are going to use is a color-composite raster (natural color image) extracted from orthoimage coverage of the region. (An *orthoimage* has been processed to correct distortions due to terrain and the geometry of image acquisition.)

Working with the Reference View, we can now use the Crosshair tool as before to add more new control points at features that we can recognize in both the input and reference images. When you are starting with an ungeoreferenced object, you should place the initial control points at features near the outer edges and corners. Additional points should be distributed as evenly as possible over the area of the object.

| ID | Column | Row    | Eastings   | Northing    | Longitude   | Latitude    | Residual (c) |
|----|--------|--------|------------|-------------|-------------|-------------|--------------|
| 5  | 498,01 | 370,81 | 688687,270 | 4537107,237 | 96,757759 W | 40,963328 N | 2,35         |
| 6  | 255,81 | 276,07 | 687875,517 | 4537381,735 | 96,767315 W | 40,965986 N | 4,45         |
| 7  | 259,05 | 153,81 | 687866,460 | 4537785,374 | 96,767300 W | 40,969621 N | 3,05         |
| 8  | 139,27 | 272,18 | 687472,486 | 4537371,731 | 96,772104 W | 40,965989 N | 2,28         |
| 9  | 401,29 | 367,59 | 688366,947 | 4537100,844 | 96,761564 W | 40,963344 N | 1,11         |
| 10 | 262,70 | 33,83  | 687858,385 | 4538185,354 | 96,767274 W | 40,973224 N | 2,25         |
| 11 | 24,37  | 402,91 | 687079,467 | 4536305,564 | 96,776912 W | 40,961882 N | 3,83         |
| 12 | 363,93 | 521,05 | 688266,799 | 4536583,803 | 96,762911 W | 40,958713 N | 3,47         |
| 13 | 159,62 | 33,94  | 687513,184 | 4538178,184 | 96,771376 W | 40,973238 N | 2,94         |




# Residuals

The Georeference process provide a mathematical assessment of the “quality” of control points in the form of *residuals*, or deviations from expected locations as computed from a mathematical model. A residual model is an equation that transforms point locations between object coordinates and map coordinates in the specified CRS. You select the mathematical form (complexity) of the equation using the Model menu. The terms in the equation are then computed automatically based on the control point coordinates. Each form of residual model has a minimum number of control points needed to satisfy the equation. Once the number of control points exceeds the minimum required, multiple solutions to the equation are possible, and a “best fit” solution can be found, as described in the sidebar.

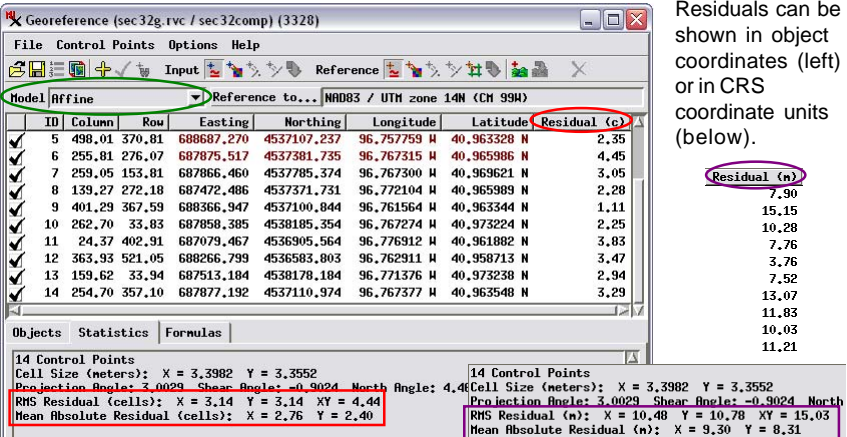
The Residual column in the control point list shows the difference between modeled and actual point positions for each control point. This distance can be shown in either object coordinates (cells for a raster object) or in the distance unit characteristic of the specified CRS (meters in our example). The overall residual for the entire set of control points, including its components in the X and Y directions, is shown in the Statistics panel.

## STEPS

- turn off the Add Control Points icon button 
- in the Georeference window choose Options / Residual Units / Meters
- note the values in the Residual column and the RMS Residual values in the Statistics panel
- choose Options / Residual Units / Cells

Using *cells* as the residual unit provides a measure that is independent of the cell size of the raster.

The “best fit” solution to the residual model has the minimum value for the Root Mean Square (RMS) error: the square root of the mean of the squared residuals for the individual control points. The individual control point residuals are the distances between modeled and actual control point locations.



The screenshot shows the Georeference window with the following details:

- Model:** Affine (circled in green)
- Reference to...:** NAD83 / UTM zone 14N (CN 994)
- Control Point List:** A table with columns for ID, Column, Row, Easting, Northing, Longitude, Latitude, and Residual (m). The Residual (m) column is circled in red.
- Statistics Panel:** Shows summary statistics for 14 control points, including RMS Residual (cells) and Mean Absolute Residual (cells).

| ID | Column | Row    | Easting    | Northing    | Longitude   | Latitude    | Residual (m) |
|----|--------|--------|------------|-------------|-------------|-------------|--------------|
| 5  | 498,01 | 370,81 | 688687,270 | 4537107,237 | 96,757759 N | 40,963328 N | 2,35         |
| 6  | 255,81 | 276,07 | 687875,517 | 4537381,735 | 96,767315 N | 40,965986 N | 4,45         |
| 7  | 259,05 | 153,81 | 687866,460 | 4537785,374 | 96,767300 N | 40,969621 N | 3,05         |
| 8  | 139,27 | 272,18 | 687472,486 | 4537371,731 | 96,772104 N | 40,965989 N | 2,28         |
| 9  | 401,29 | 367,59 | 688366,947 | 4537100,844 | 96,761564 N | 40,963344 N | 1,11         |
| 10 | 262,70 | 33,83  | 687858,385 | 4538185,354 | 96,767274 N | 40,973224 N | 2,25         |
| 11 | 24,37  | 402,91 | 687079,467 | 4536905,564 | 96,776912 N | 40,961882 N | 3,83         |
| 12 | 363,93 | 521,05 | 688266,799 | 4536583,803 | 96,762911 N | 40,958713 N | 3,47         |
| 13 | 159,62 | 33,94  | 687513,184 | 4538178,184 | 96,771376 N | 40,973238 N | 2,94         |
| 14 | 254,70 | 357,10 | 687877,192 | 4537110,974 | 96,767377 N | 40,963548 N | 3,29         |

**Statistics Panel:**

- 14 Control Points
- Cell Size (meters): X = 3,3982 Y = 3,3552
- Projection Angle: 3,0029 Shear Angle: -0,9024 North
- RMS Residual (cells): X = 3,14 Y = 3,14 XY = 4,44
- Mean Absolute Residual (cells): X = 2,76 Y = 2,40

**Statistics Panel (continued):**

- 14 Control Points
- Cell Size (meters): X = 3,3982 Y = 3,3552
- Projection Angle: 3,0029 Shear Angle: -0,9024 North
- RMS Residual (m): X = 10,48 Y = 10,78 XY = 15,03
- Mean Absolute Residual (m): X = 9,30 Y = 8,31

Residuals can be shown in object coordinates (left) or in CRS coordinate units (below).

# Residual Models

## STEPS

- in the Options menu on the Input View, make sure that the Warp to Model option is toggled on
- choose Plane Projective from the Model menu on the Georeference window

When the Warp to Model option is turned on for the Input View, the input object is automatically reprojected to the reference CRS using the current residual model and control points.

Use the Model menu to choose the mathematical form of the residual model. Using a model appropriate for the input makes it easier to spot blunders in control point placement.

High residual values for one or more control points may result from errors in identifying corresponding locations in the input and reference objects. However, even when control points are “correctly” placed, high residuals may persist for some control points. For aerial and satellite images, high residuals may result from spatial shifts of image features by different amounts and in different directions (distortion) due to topography (relief displacement), a non-vertical angle of acquisition (tilt distortion), or the optics of the imaging system.

The Georeference process provides a number of residual models with different degrees of mathematical complexity to account for different types of spatial distortion that might be present in the data you are georeferencing. The minimum number of non-collinear points required to compute residuals increases with increasing model complexity. Some of the more commonly used residual models are shown in the table at the bottom of the page.

The aerial image we are georeferencing suffers from tilt distortion and local relief displacement effects.

| Model                               | Plane Projective | Reference to... | NAD83 / UTM zone 14N (CH 99M) |            |             |             |             |              |
|-------------------------------------|------------------|-----------------|-------------------------------|------------|-------------|-------------|-------------|--------------|
|                                     | ID               | Column          | Row                           | Easting    | Northing    | Longitude   | Latitude    | Residual (c) |
| <input checked="" type="checkbox"/> | 5                | 498,01          | 370,81                        | 689687,270 | 4537107,237 | 96,757759 W | 40,963328 N | 0,56         |
| <input checked="" type="checkbox"/> | 6                | 255,81          | 276,07                        | 687875,517 | 4537381,735 | 96,767315 W | 40,965986 N | 1,68         |
| <input checked="" type="checkbox"/> | 7                | 259,05          | 153,81                        | 687866,460 | 4537785,374 | 96,767300 W | 40,969621 N | 1,45         |
| <input checked="" type="checkbox"/> | 8                | 139,27          | 272,18                        | 687472,486 | 4537371,731 | 96,772104 W | 40,965989 N | 1,16         |
| <input checked="" type="checkbox"/> | 9                | 401,29          | 367,59                        | 688366,947 | 4537100,844 | 96,761564 W | 40,963344 N | 0,81         |
| <input checked="" type="checkbox"/> | 10               | 262,70          | 33,83                         | 687858,385 | 4538185,354 | 96,767274 W | 40,973224 N | 1,32         |
| <input checked="" type="checkbox"/> | 11               | 24,37           | 402,91                        | 687079,467 | 4536905,564 | 96,776912 W | 40,961882 N | 0,68         |
| <input checked="" type="checkbox"/> | 12               | 363,93          | 521,05                        | 688266,799 | 4536583,803 | 96,762911 W | 40,958713 N | 1,30         |
| <input checked="" type="checkbox"/> | 13               | 159,62          | 33,94                         | 687513,184 | 4538178,184 | 96,771376 W | 40,973238 N | 0,89         |
| <input checked="" type="checkbox"/> | 14               | 254,70          | 357,10                        | 687877,192 | 4537110,974 | 96,767377 W | 40,963548 N | 0,96         |

The Plane Projective residual model compensates for the tilt distortion, resulting in lower residuals compared to the default Affine model.

Our control points show lower residuals when the Plane Projective model is used rather than the Affine model.

### A sample of commonly-used residual models

| Model              | Minimum Points / Description                                     |
|--------------------|--|
| Affine             | 3 Linear scaling in X and Y directions, rotation, shear          |
| Plane Projective   | 4 Projection between non-parallel planes, models tilt distortion |
| Order 2 Polynomial | 6 Models variable non-linear distortions                         |

For a full listing of residual models see the Technical Guide entitled *Georeference: Choosing a Model*.

# Select, Disable and Enable Control Points

Each control point in the list has a checkbox control on the left to disable or enable the point. Changing the status of any point automatically causes a new residual model to be computed using only the currently enabled control points. You can therefore toggle the status of individual points to assess the effect on the residual values for other control points and the overall RMS residual value for all enabled points. Residuals continue to be shown for the disabled points, and are typically higher than for enabled points.

Enabled and disabled control points are shown in the views in different colors. Points you have selected in the list are shown in a third color. You can assign colors for enabled, disabled, and selected points by choosing Options / Colors from the Georeference window. Selections on the Control Points menu allow you to enable or disable all points.

Disabling points allows you to identify problematic points that you may want to reposition or delete. You can delete any selected points using the Delete icon button, or delete all disabled points using an option on the Control Points menu.

You can select one or more control points in the list for deletion or other operations.

## STEPS

- left-click on the list entry for any control point to select it
- hold down the Shift key while clicking on two list entries to select a range of points
- hold down the Ctrl key while clicking on a list entry to toggle selection on or off
- turn off the Enable/Disable checkbox for several points with high residual values and note the effect on residuals for the enabled points

Select Colors window for selecting colors to indicate the status of individual control points in the views.

The screenshot shows the Georeference software window with the following data:

| ID | Column | Row    | Easting    | Northing    | Longitude   | Latitude    | Residual (c) |
|----|--------|--------|------------|-------------|-------------|-------------|--------------|
| 1  | 28.55  | 35.43  | 687050.713 | 4538165.406 | 96.776873 N | 40.973230 N | 0.67         |
| 2  | 505.75 | 36.67  | 688659.088 | 4538204.756 | 96.757759 N | 40.973214 N | 4.17         |
| 3  | 494.80 | 525.14 | 688699.611 | 4536593.916 | 96.757769 N | 40.958704 N | 1.20         |
| 4  | 24.35  | 501.64 | 687089.011 | 4536559.215 | 96.776903 N | 40.958763 N | 0.62         |
| 5  | 498.01 | 370.81 | 688687.270 | 4537107.237 | 96.757759 N | 40.963328 N | 0.69         |
| 6  | 255.81 | 276.07 | 687875.517 | 4537381.735 | 96.767315 N | 40.965986 N | 1.59         |
| 7  | 259.05 | 453.81 | 687866.460 | 4537785.374 | 96.767300 N | 40.969621 N | 0.86         |
| 8  | 139.27 | 272.18 | 687472.486 | 4537371.731 | 96.772104 N | 40.965989 N | 1.21         |
| 9  | 401.29 | 367.59 | 688366.947 | 4537100.844 | 96.761564 N | 40.963344 N | 0.87         |
| 10 | 262.70 | 33.83  | 687858.385 | 4538185.354 | 96.767274 N | 40.973224 N | 0.90         |

Summary statistics from the bottom of the window:

- 14 Control Points: 12 Enabled; 2 Disabled
- Cell Size (meters): X = 3.3852 Y = 3.3464
- Projection Angle: 2.6350 North Angle: 4.0995
- RMS Residual (Enabled, cells): X = 0.57 Y = 0.71 XY = 0.91
- RMS Residual (Disabled, cells): X = 1.13 Y = 2.95 XY = 3.15
- Mean Absolute Residual (Enabled, cells): X = 0.50 Y = 0.57
- Mean Absolute Residual (Disabled, cells): X = 1.02 Y = 2.32





Control point list with several high-residual control points disabled.



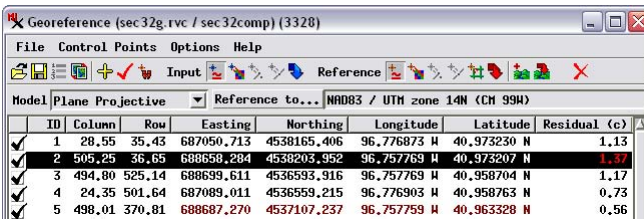
# Edit Control Points

## STEPS

- choose Enable All from the Control Points menu
- zoom in on a control point with a high residual value
- left-click on that point's entry in the control point list to select it
- turn on the Crosshair tool
- adjust the point position in the Input or Reference view (or both)
- press Apply to accept the changes 
- when you are satisfied with the set of control points, press Save to save the georeference subobject 

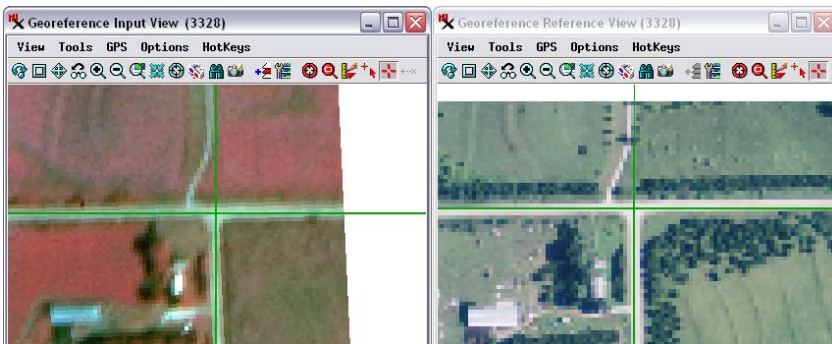
When the Add Control Points mode is turned off, you can edit (adjust the position of) any existing control point. You must first select the point to be edited in the control point list. The icon button for the currently available placement tool (Crosshair or Tie Point) then is activated in the Input View (and Reference View if open) and can be turned on. The numbered control point symbol is then replaced in the views by the tool graphic, allowing you to edit the point position graphically. The residual value for the point is automatically updated as you make changes in the point position in either view, allowing you to preview the effect of your changes. You can also edit any of the coordinate values for the point directly in its fields in the control point list.

When you have finished editing the point, pressing the Apply button accepts your changes. If you select another point in the list before applying the changes, a dialog window pops up to ask whether you want to apply the changes to the active point.



| ID | Column | Row    | Easting    | Northing    | Longitude   | Latitude    | Residual (c) |
|----|--------|--------|------------|-------------|-------------|-------------|--------------|
| 1  | 28.55  | 35.43  | 687050.713 | 4538165.406 | 96.776873 W | 40.973230 N | 1.13         |
| 2  | 505.25 | 36.65  | 688658.284 | 4538203.952 | 96.757789 W | 40.973207 N | 1.37         |
| 3  | 494.80 | 525.14 | 688699.611 | 4536593.916 | 96.757769 W | 40.958704 N | 1.17         |
| 4  | 24.35  | 501.64 | 687089.011 | 4536559.215 | 96.776903 W | 40.958763 N | 0.73         |
| 5  | 498.01 | 370.81 | 688687.270 | 4537107.237 | 96.757759 W | 40.963328 N | 0.56         |

When the views are zoomed in, selecting a different point to edit automatically zooms both views to the newly selected point.









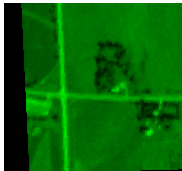
## Raster / Raster Overlay

When both the input and reference are raster objects, you can add the reference raster as an overlay in the Input View. You can add the overlay in one of a number of special display modes that show the input raster and the partially-transparent reference overlay in shades of separate complementary colors. Different color combinations may work better than others for particular images, depending on the image colors present; you can easily switch combinations until you find one that shows features clearly in both images. In this exercise we use green shades for the input image and red shades for the reference. In places where bright features (such as the roads) are well-aligned, the green and red add to create yellow. Where the images are misaligned, color fringes or offset duplicate features are visible.

You also have the option to overlay the reference in full color. When you use that option, be sure to open the Raster Layer Controls for the reference and on the Options panel set a transparency value for the overlay.

### STEPS

- open raster COMP2 from the SEC32G Project File as the input object 
- on the Input View, choose Options / Raster/Raster Overlay / Green-Red
- in the Input View sidebar legend or Layer Manager, click on the raster layer name to make it the active layer
- add the SEC32ORTHO raster from the SEC32G Project File to the Input View 
- press the Add Control Points icon button on the Georeference window 
- turn on the Tie Point tool in the Input View 

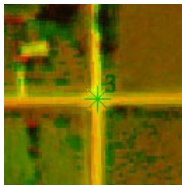


Input raster in green-scale

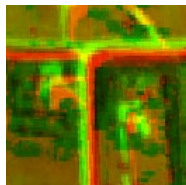


Reference raster in red-scale

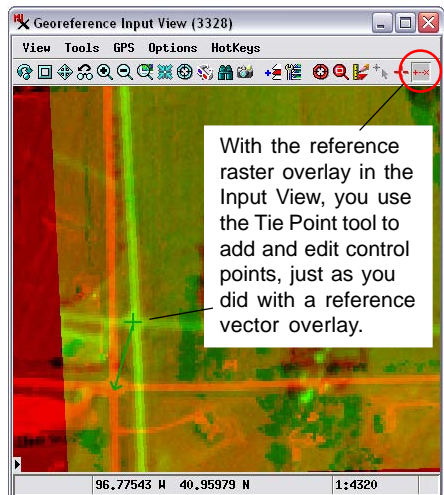
### Bright road features in Green-Red:



Good registration: bright roads coincide as yellow.





Poor registration: offset green and red road features.



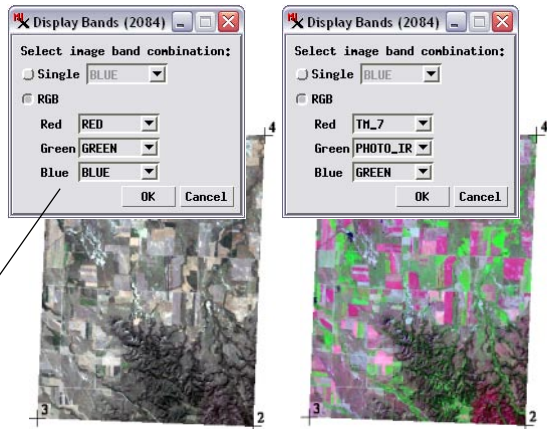
Overlay of reference and input rasters using Green-Red color scheme.

# Multiband Image Input

## STEPS

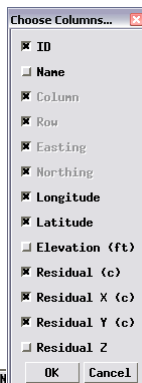
- ☑ press the Open icon button 
- ☑ navigate to the CB\_DATA data collection and into the CB\_TM Project File
- ☑ choose rasters BLUE, GREEN, RED, PHOTO\_IR, TM\_5, and TM\_7
- ☑ press [OK] on the Display Bands dialog that opens
- ☑ on the Georeference window press the Image Band Combination icon button 
- ☑ in the Display Bands dialog, choose TM\_7 for Red, PHOTO\_IR for Green, and GREEN for Blue

You can select and simultaneously georeference all bands of a multiband image that have the same cell size and dimensions. After you select the raster objects, you are automatically prompted to choose any single band or any 3-band RGB combination of bands to display in the Georeference Input View. (You can change this display combination at any time using the Image Band Combination icon button on the Georeference window.) When you save georeference information, it is automatically saved to all of the selected image bands.



If there are bands named Red, Green, and Blue, the Display Bands dialog automatically assigns them to the corresponding color channel for display. However, you can choose any RGB combination of the bands to display in the Input View.

- ☑ from the Options menu in the Georeference window, choose Columns
- ☑ in the Choose Columns dialog window, turn on the toggle buttons for Residual X and Residual Y



The Georeference process by default shows only the total residual for each point in the control point list. You can add columns for X and Y residuals from a dialog opened by choosing Options / Columns. You can also choose whether to show columns for elevation, the secondary CRS coordinate columns, and a point name field.

Added columns for X and Y residuals


| ▲ ID | Column | Row    | Easting    | N          | Latitude     | Residual (c) | Residual X (c) | Residual Y (c) |       |
|------|--------|--------|------------|------------|--------------|--------------|----------------|----------------|-------|
| ✓ 1  | 0,00   | 0,00   | 333354,597 | 162833,243 | 103,375000 N | 42,750000 N  | 0,18           | 0,18           | -0,00 |
| ✓ 2  | 361,00 | 488,00 | 343050,582 | 148959,581 | 103,250000 N | 42,625000 N  | 0,18           | 0,18           | 0,00  |
| ✓ 3  | 0,00   | 488,00 | 332803,913 | 148958,736 | 103,375000 N | 42,625000 N  | 0,18           | -0,18          | -0,00 |
| ✓ 4  | 361,00 | 0,00   | 343580,881 | 162434,883 | 103,250000 N | 42,750000 N  | 0,18           | -0,18          | 0,00  |

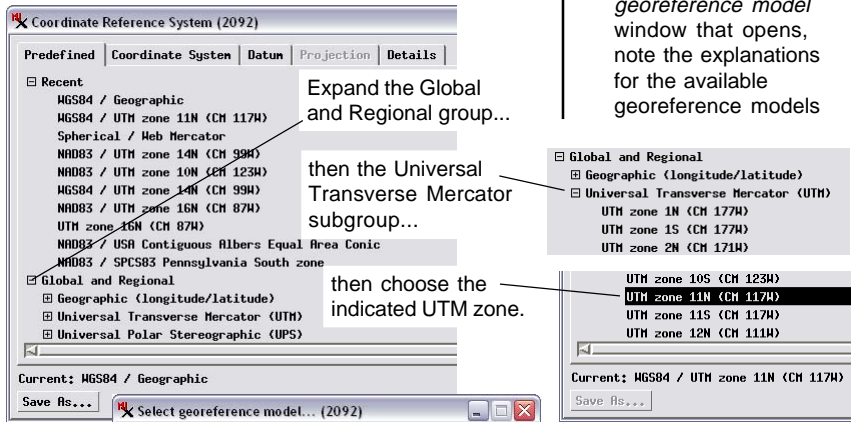
# Ungeoreferenced Input

In the Georeference process, selecting a spatial object lacking georeference as input triggers the appearance of a sequence of dialog windows. The Coordinate Reference System window appears first, enabling you to designate the spatial referencing system (datum and coordinate system) to use to georeference the object. This is the standard dialog window used throughout the TNT products for this purpose (see the Tutorial entitled *Coordinate Reference Systems* for further details).

After you set the coordinate reference system, the *Select georeference model* window appears and presents the georeference models available for the type of input object you have selected. A description of the selected model appears in the right side of this window to provide context for your choice.

## STEPS

- in the Georeference window, open raster SIMPLE.RVC /  LKMEAD from the GEOREF data collection
- in the Coordinate Reference System window that opens, expand the Global and Regional group on the Predefined tabbed panel
- expand the Universal Transverse Mercator (UTM) subgroup
- scroll down and select UTM zone 11N (CM 117)
- press [OK] in the Coordinate Reference System window
- in the *Select georeference model* window that opens, note the explanations for the available georeference models



Explanations are provided for the georeference models in the *Select georeference model* window.

- keep the *Select georeference model* window open and proceed to the next exercise

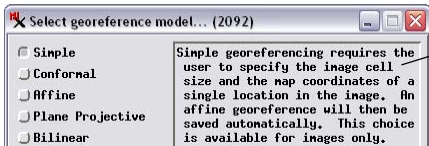
# Simple Georeference

**STEPS**

- choose Simple on the *Select georeference model* window and press [OK]
- in the Create Simple Image Georeference window that appears, enter 30 in the Column and Row fields in the Cell Size groupbox
- choose Upper Left Corner from the Image Location menu
- in the Coordinates groupbox, enter 707280 in the Easting Field
- enter 4013640 in the Northing field
- keep the default setting of Projection Upright on the Orientation menu
- press [OK] on the Create Simple Image Georeference window

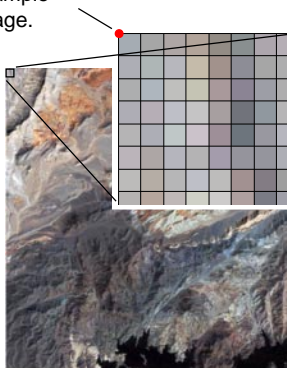
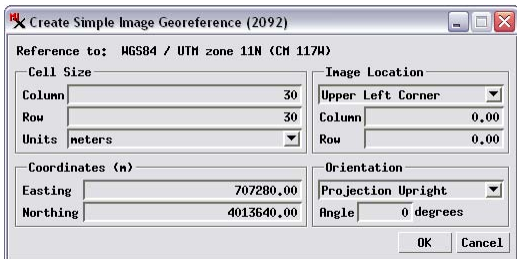
In some cases you may acquire images with georeference information only in a nonstandard metadata or text file that cannot be automatically parsed by TNTmips during import. This georeference information is most often in the form of *simple georeference*, which specifies the size of image cells and the reference coordinates for a designated reference point in the image (most commonly the upper left corner). In most cases image rows and columns are exactly aligned to the map grid of the coordinate reference system (projection upright), but other orientations can be specified as well.

The choice of simple georeference is presented in the *Select georeference model* window as an alternative to designating a residual model for control point georeference. You can then enter the required parameters in the Create Simple Image Georeference window. When all parameters have been set and you press OK on this window, affine georeference parameters are computed and automatically saved for the input object, completing the process.



The choice of Simple georeference is integrated with georeference model selection.

The reference location in this example is the upper left corner of the image.



To set up Simple georeference specify the raster cell size, the reference point location in the image, its reference coordinates, and the image orientation.

---

## Advanced Features

**Auto-Register** Creating georeference control points manually for a large aerial or satellite image to improve its registration to reference geodata can be a time-consuming task. The Auto-Register operation in the Georeference process automatically generates hundreds to thousands of control points for an input image using a reference image of the same area. The reference image you use does not have to match the cell size, coordinate reference system, or extents of the input image. The reference image can be a single grayscale raster, an RGB display of separate image bands, or a color-composite raster. It can reside in a TNT Project File, any image file format supported for direct use (GeoTIFF, GeoJP2, ...), or in a standard web tileset structure (Google Maps, Google Earth, or Bing Maps) on your local network or on the web, including the publicly-available web tilesets hosted by MicroImages. For accurate results you should use a reference image with spatial resolution equal to or better than that of the input.

**Import GPS Control Points** If ground control points have been acquired in a GPS survey over the area of your input data, the GPS points can be imported directly from standard GPX, CSV, or text files to use as georeference control points. Map coordinates from a GPX file are automatically converted to the reference coordinate reference system if necessary.

**Snap to Map Grid** For input objects that include map grid lines or grid intersection tick marks, such as scanned topographic maps, the Snap to Grid mode on the Reference toolbar lets you quickly enter control points with the appropriate map coordinates. You define a virtual map grid that specifies the coordinate reference system and grid line spacings found in the input object. Once the virtual grid is established, placing the Crosshair tool in the Input View automatically sets that control point's map coordinates to those of the nearest virtual grid intersection.

**Transfer Georeference** Some satellite images include image bands with different spatial resolutions (cell sizes). Once you have georeferenced the higher-resolution bands, the Transfer Georeference operation in the Georeference process allows you to transfer that georeference to the lower-resolution bands, with appropriate adjustments for the differing cell sizes.

More information about these and other features can be found in the a series of Georeference Technical Guides available at [microimages.com](http://microimages.com), including:

*Overview*

*Choosing a Model*

*Control Point List*

*Simple and Implied*

*Auto-Register to Reference Image*

*Auto-Register Landsat 5 to a Global Web Tileset*

*Import GPS Control Points from GPX File*

*Snap Control Points to Elements or Reference Grid*

*Multiband and Multiresolution Images*

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