Lab #10 Digital Orthophoto Creation (Using Leica Photogrammetry Suite)

References: Leica Photogrammetry Suite™ Project Manager: Users Guide, Leica Geosystems LLC.
Leica Photogrammetry Suite 9.2

Introduction:

The Leica Photogrammetry Suite drastically reduces the cost and time associated with triangulating and orthorectifying aerial photography, satellite imagery, digital, and video camera imagery when collecting geographic information. Reliable geographic information can not be collected from raw aerial photography or satellite imagery due to geometric distortions resulting from various systematic and nonsystematic errors. These errors occur from camera and sensor orientation, terrain relief, Earth curvature, film and scanning distortion, and measurement errors. Leica Photogrammetry Suite uses the most reliable geometric modeling method called the collinearity equation based orthorectification. This process incorporates the sensor or camera orientation, relief displacement, and the Earth's curvature in its modeling process. Orthorectification in Leica Photogrammetry Suite produces planimetrically true orthoimages where all geometric errors are removed. The orthoimage has the geometric characteristics of a map and the image qualities of a photograph.

This lab will utilize Leica Photogrammetry Suite to create orthophotos of your aerial photos (EF-I-5, EF-I-6, and EF-I-7). To create orthophotos with Leica Photogrammetry Suite you must have the following camera information:

1. Camera Focal Length (mm)
2. Principal Point x offset (mm)
3. Principal Point y offset (mm)
4. Fiducial (x,y) coordinate locations (mm)
5. Average above ground flying height (meters)

This information can be located within the camera calibration report or with the aerial photography/flight planning report, which can be acquired from the company that flew the project area.

In this lab, you are going to perform the following basic steps:

- Create ERDAS IMAGINE (.img) files from scanned aerial photographs in TIFF format (.tiff)
- Create a new Leica Photogrammetry Suite (LPS) project block file
- Add imagery to the block file
- Define the camera model
- Measure ground control points (GCP) and check points
- Use the automatic tie point collection function
- Triangulate the images
- Orthorectify the images

In order to create orthophotos, you must have an aerial photo in digital format. Desktop scanners can be used to scan film or paper based photographs. Aerial photo film is superior to paper, both in terms of image detail and geometry. When using a desktop scanner, you should make sure that the active area is at least 9 X 9-inches (i.e., A3 type scanner), enabling you to capture the entire photo frame. **An 8.5 X 11-inch scanner will not capture an entire 9 X 9-inch aerial photograph.** LPS utilizes the photo fiducial marks to define the photo interior orientation.

The required pixel resolution varies depending on the application. Aerial triangulation and feature collection applications often scan in the 10- to 15-micron range. One micron (micrometer) is equivalent to 1/25400ths of an inch. Orthophoto applications often use 15- to 30-micron pixels. Color film is less sharp than panchromatic, therefore color ortho applications often use 20- to 40-micron pixels. Table 1 lists the

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scanning resolutions associated with various scales of photography and image file size. File size is based on an ERDAS Imagine (.img) format. (**NOTE**: Files with a .img extension may or may not be an ERDAS Imagine formatted file. Other .img extensions exist that are not compatible with the ERDAS Imagine software, i.e., GEM Paint (.img) formatted files.) The ground coverage column refers to the ground coverage per pixel. Thus, a 1:9600 scale photograph scanned at 16 microns (1588 dpi) has a ground coverage per pixel of 0.1536 meter by 0.1536 meter. The resulting B/W file size is approximately 84 MB, assuming a square 9 X 9 inch photograph.

Your school forest photos have been scanned to a TIFF (Tag Image File Format) formatted image file. This file is formatted to a 400 x 400 pixel per inch image resolution.

Question #1:
Determine the exact ground coverage per pixel of your scanned forest photos. _____ meters

Question #2:
Convert the scanning resolution from pixels per inch to microns. _____ microns

Table 1: Scanning Resolutions

Photo Scale 1 to	12 microns (2117 dpi) Ground Coverage (meters)	16 microns (1588 dpi) Ground Coverage (meters)	25 microns (1016 dpi) Ground Coverage (meters)	50 microns (508 dpi) Ground Coverage (meters)	85 microns (300 dpi) Ground Coverage (meters)
1800	0.0216	0.0288	0.045	0.09	0.153
2400	0.0288	0.0384	0.06	0.12	0.204
3000	0.036	0.048	0.075	0.15	0.255
3600	0.0432	0.0576	0.09	0.18	0.306
4200	0.0504	0.0672	0.105	0.21	0.357
4800	0.0576	0.0768	0.12	0.24	0.408
5400	0.0648	0.0864	0.135	0.27	0.459
6000	0.072	0.096	0.15	0.3	0.51
6600	0.0792	0.1056	0.165	0.33	0.561
7200	0.0864	0.1152	0.18	0.36	0.612
7800	0.0936	0.1248	0.195	0.39	0.663
8400	0.1008	0.1344	0.21	0.42	0.714
9000	0.108	0.144	0.225	0.45	0.765
9600	0.1152	0.1536	0.24	0.48	0.816
10800	0.1296	0.1728	0.27	0.54	0.918
12000	0.144	0.192	0.3	0.6	1.02
15000	0.18	0.24	0.375	0.75	1.275
18000	0.216	0.288	0.45	0.9	1.53
24000	0.288	0.384	0.6	1.2	2.04
30000	0.36	0.48	0.75	1.5	2.55
40000	0.48	0.64	1	2	3.4
50000	0.6	0.8	1.25	2.5	4.25
60000	0.72	0.96	1.5	3	5.1
B/W File Size (MB)	363	204	84	21	7
Color File Size (MB)	1089	612	252	63	21

Viewing a TIFF file in ERDAS IMAGINE

1. Start ERDAS IMAGINE.

2. Click the open layer button within the Viewer that automatically opens when starting ERDAS

   IMAGINE.

3. Navigate to C:\FOR_375\Data_files\Orthophoto Generation

4. Next to the **Files of type**, click on the pull down menu, and select **TIFF (*.tiff),** select image EF-I-5.

5. Before pressing Enter, select the **Raster Options** tab at the top of the Select Layer To Add dialog.

6. Under **Layers to Colors:**, display band **1** in the **Red:** color gun, band **2** in the **Green:** color gun, and

   band **3** in the **Blue:** color gun.

7. Click the **Fit to Frame** check box to fit the image to the current Viewer window size.

8. Click **OK** to close the Select Layer To Add dialog (click yes if prompted for pyramid layer creation).
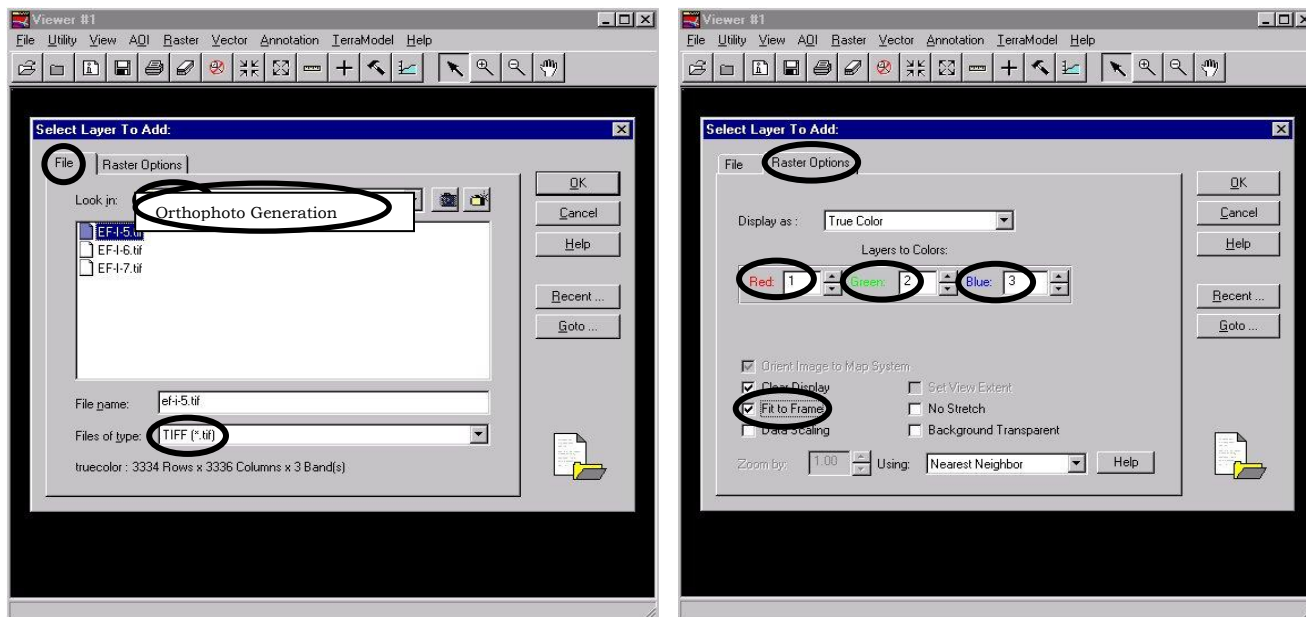
Your selected photo image will appear within the viewer. Zoom in on the image by selecting the **Zoom In** button located on the Viewer display screen. Click on the image within the Viewer to zoom in. The level of detail this photo has with a 400 x 400-pixels per inch (PPI) resolution size, and the photos have been scanned so that north is at the top.

NOTE: Leica Photogrammetry Suite requires scanned images to be in the ERDAS IMAGINE (.img) image format.

Converting TIFF (.tiff) Image Format to ERDAS IMAGINE (.img) Image Format

1. Click on the Import icon on the ERDAS IMAGINE icon panel (bar panel at the top).

The Import button is enabled when the dialog first opens, so that all of the prompts that display in the dialog are for importing data. When you click on the Export buttons, the prompts change to options for exporting data.

2. Click on the **Type:** popup list to select **TIFF** from the list of available importers.

3. Click on the **Media:** popup list to select **File**.

4. Within the **Input File (*.tif)** window, navigate to
     "C:\FOR_375\Data_Files\Orthophoto Generation" and select **EF-I-5.tif**.

5. Within the **Output File (*.img)** window, navigate to
    "C:\FOR_375\Data_Files\Orthophoto Generation" and name your file **EF-I-5.img**.

6. In the Import/Export dialog, click **OK**.
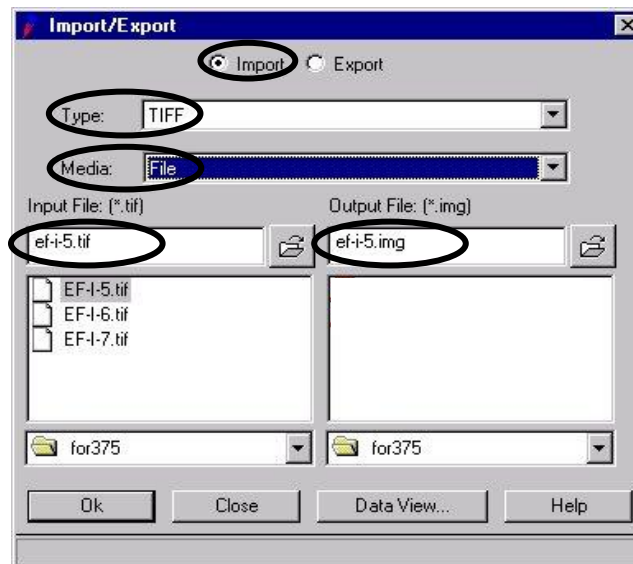
7. The Import TIFF dialog opens:
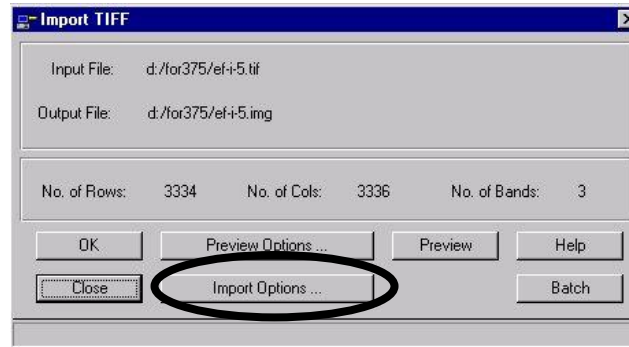
8. In the Import TIFF dialog window, click **Import Options.**
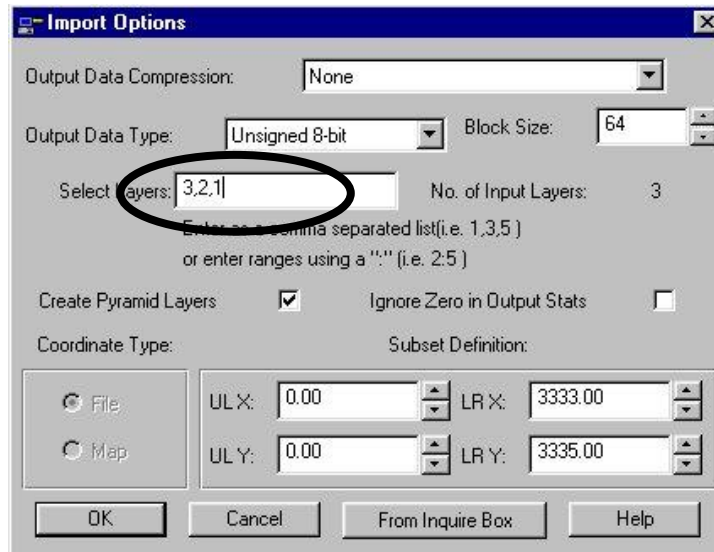
9. In the Import Options dialog, type **3,2,1** in the Select Layers: selection box.
Since ERDAS Imagine loads the first three bands in the red, green, and blue color guns, importing the image as 3,2,1 will load the appropriate spectral bands into the proper color guns.

10. Click **OK** in the Import Options dialog.

11. In the Import TIFF dialog, click **OK**.

12. When the Job Status dialog indicates **Done**, click **OK** to dismiss the Job Status dialog. Your selected TIFF file has been successfully imported into an ERDAS IMAGINE (.img) formatted file.
Import the other two TIFF images (6 & 7) into an ERDAS IMAGINE (.img) file format by repeating the previous steps. Make sure that all your files are being placed in the "C:\FOR_375\Data_Files\Section_?" directory (replace "?" with your section number (1,2 or 3) . When you've completed importing all the TIFF images to ERDAS IMAGINE (.img) file format, click **Close** on the Importing TIFF Data dialog.
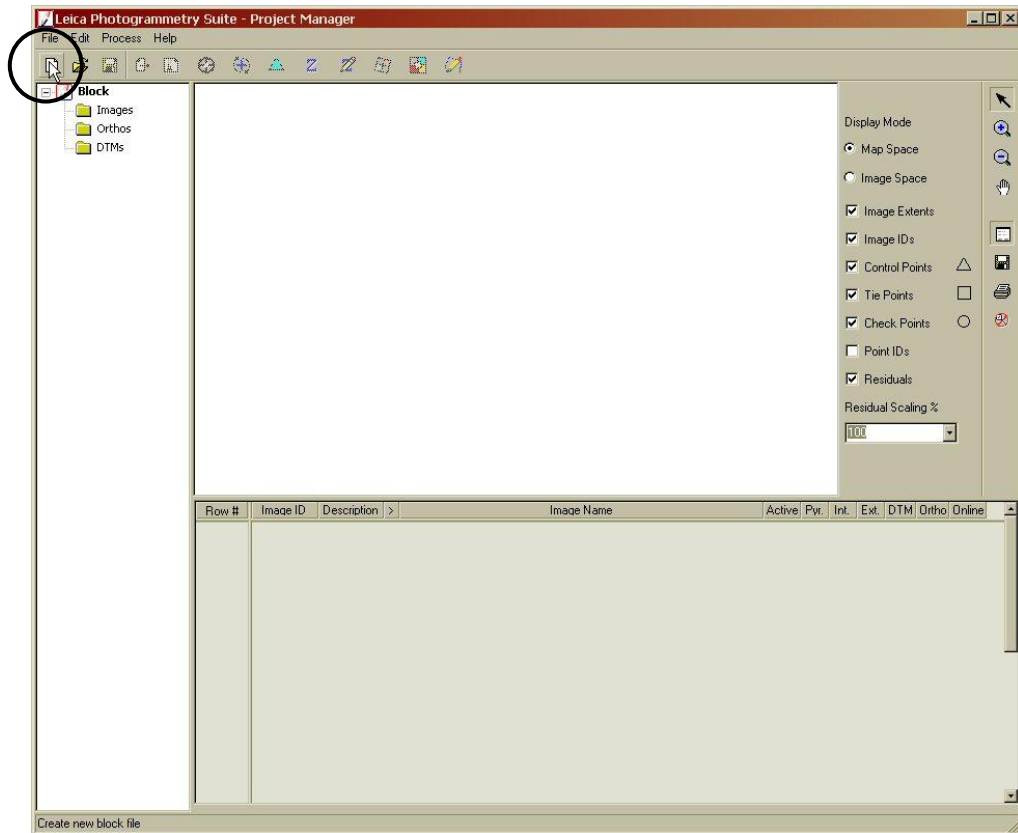
Starting the Leica Photogrammetry Suite and Preparing the Block File:

You're now ready to start the Leica Photogrammetry Suite to create orthophotos.

1. Close all Viewers that are currently open.

2. Select **Main | LPS…** from the IMAGINE menu bar, or click the Leica Photogrammetry Suite icon on the ERDAS IMAGINE icon panel.

3.

The LPS Project Manager window opens.

4. Click the button to **Create a New Block File**.

The Create New Block File dialog opens

5. Navigate to **C:\FOR_375\Section_?**. Next to **File name**, type **ortho_lab.blk**, then press Enter on your keyboard.

When you use the Leica Photogrammetry Suite, you create block files. Block files have the .blk extension. A block file may be made up of only one image, a strip of images that are adjacent to one another, or several strips of imagery (i.e. "a block").

The .blk file is a binary file. In it is all the information associated with the block including imagery locations, camera information, fiducial mark measurements, and GCP measurements.

Click **OK** to close the Create New Block File dialog. The Model Setup dialog opens.
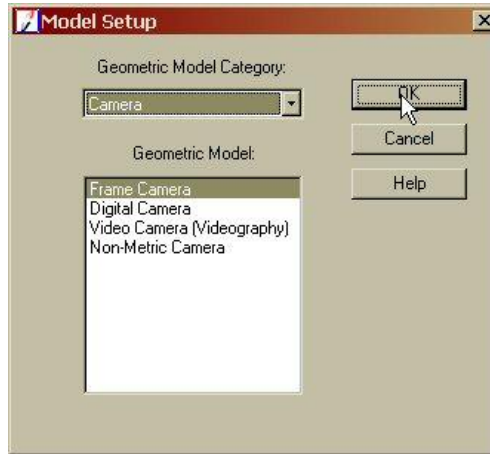
5. From the **Select Geometric Model** list, select **Frame Camera**.

6. Click **OK** to close the Model Setup dialog.

   The Block Property Setup dialog opens.
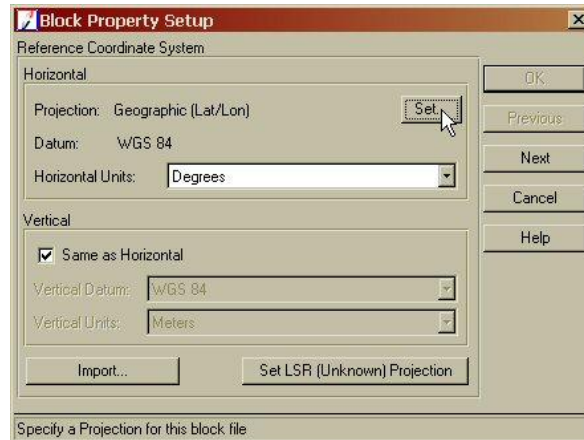
7. Click the **Set Projection** button in the **Set Reference System** section of the Block Property Setup dialog.

8. Click the **CUSTOM** tab on the Projection Chooser dialog. Select the projection information that is consistent with your reference source image (see next step).

9. In this exercise, you will orthorectify your three school forest images (EF-I-5,6,7) to the same projection as a 1992, 1-meter resolution, USGS Digital Ortho Quad (DOQ). This DOQ is formatted to the following projection:

> Projection Type: UTM
> Spheroid Name: Clarke 1866
> Datum Name: NAD27
> UTM Zone: 11
> North or South: North

Warning: Ensure that the information you provide in the Set Reference System section of the Block Property Setup dialog is accurate. You are unable to return to this stage of the block setup process to change projection information once it has been set.

10. Set the Vertical details so that the Spheroid and Datum names are both **Clarke 1866**, Elevation Units are **meters** and elevation type **height**. Click **OK** on the Elevation Info Chooser to accept the projection information.

11. Click **Next** in the Block Property Setup dialog.
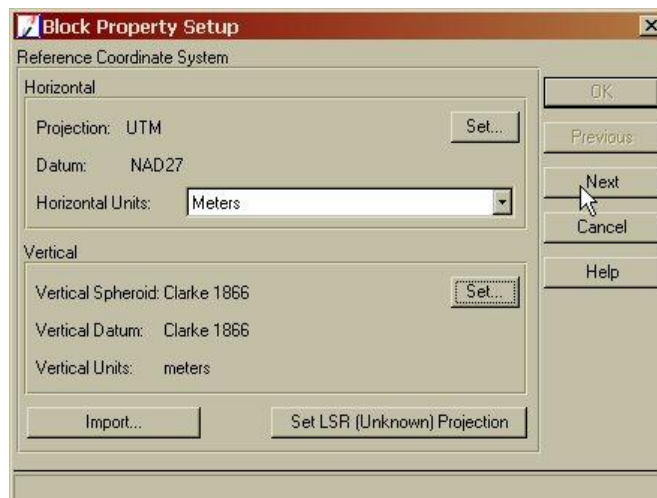
The **Set Frame-Specific Information** section displays.
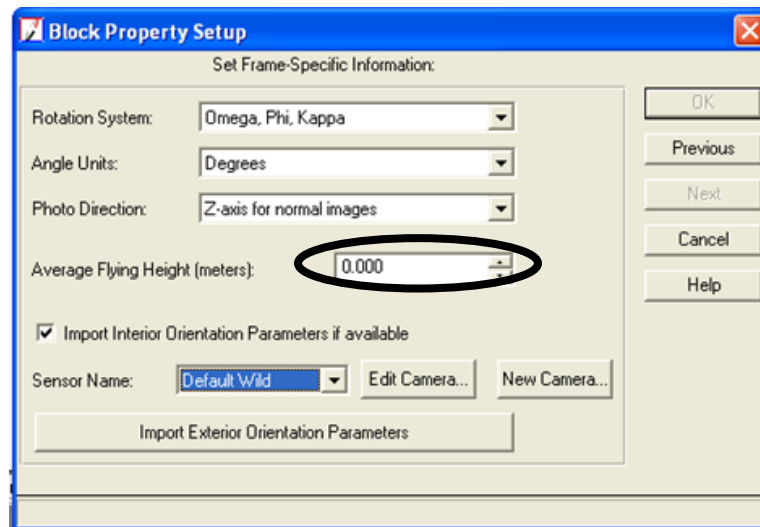
12. The average flying height for your school photos is 15,090 feet above the ground. **Convert this value to meters** and enter it into the number field.

The **Rotation System:** should be set to **Omega, Phi, Kappa; Angle Units to Degrees** and the **Photo Direction** set to **Z-axis for normal images**.

Rotation System: This popup list is used to select the type of rotation angle appropriate for the data to be used in the block. Different countries sometimes use different rotation systems.
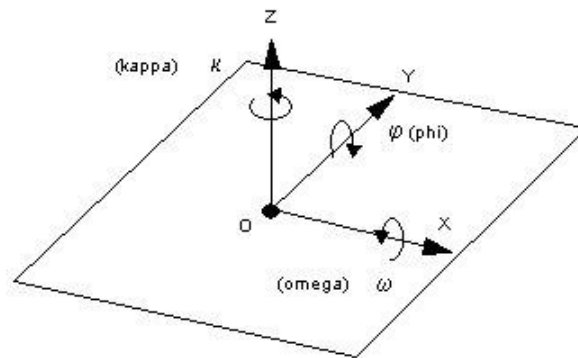
Omega, Phi and Kappa define the orientation of the sensor as it existed when the photograph or imagery was captured. The three rotation angles define the relationship between the axis of the ground system and the image coordinate system. The rotation angles are used to form a 3 by 3 rotation matrix, which is used within the aerial triangulation functional model (i.e. block bundle adjustment).

The primary axis is the axis about which the first rotation occurs. Rotation follows the right-hand rule which says that when the thumb of the right hand points in the positive direction of an axis, the curled fingers point in the direction of positive rotation for that axis.

> **Omega, Phi, Kappa:** This is the most commonly used convention, recommended by ISPRS. **Omega** is a positive rotation around the X-axis; **Phi** is a positive rotation around the Y-axis; **Kappa** is positive rotation around the Z-axis. In this system, X is the primary axis.

> **Phi(+), Omega, Kappa** In this system, which is most commonly used in Germany, Y is the primary axis. **Phi** is a positive rotation around the Y-axis; **Omega** is a positive rotation around the X-axis; **Kappa** is a positive rotation around the Z-axis.

> **Phi(-), Omega, Kappa** In this system, which is most commonly used in China, Y is the primary axis. **Phi** is a negative rotation around the Y-axis; **Omega** is positive rotation around the X-axis; **Kappa** is a positive rotation around the Z-axis.

Photo Direction: This popup list is used to select the direction appropriate for the data to be used in the block project.

> **Z-axis for normal images** Select this option if using aerial photography for your block project. Aerial photographs have the optical axis of the camera directed toward the Z-axis of the ground coordinate system.

> **Y-axis for close-range images** Select this option when using ground-based photography. Terrestrial or ground-based photographs have the optical axis of the camera directed toward the Y-axis of the ground coordinate system.

13. Click **OK** to close the Block Property Setup dialog.

    The main IMAGINE OrthoBASE dialog opens.
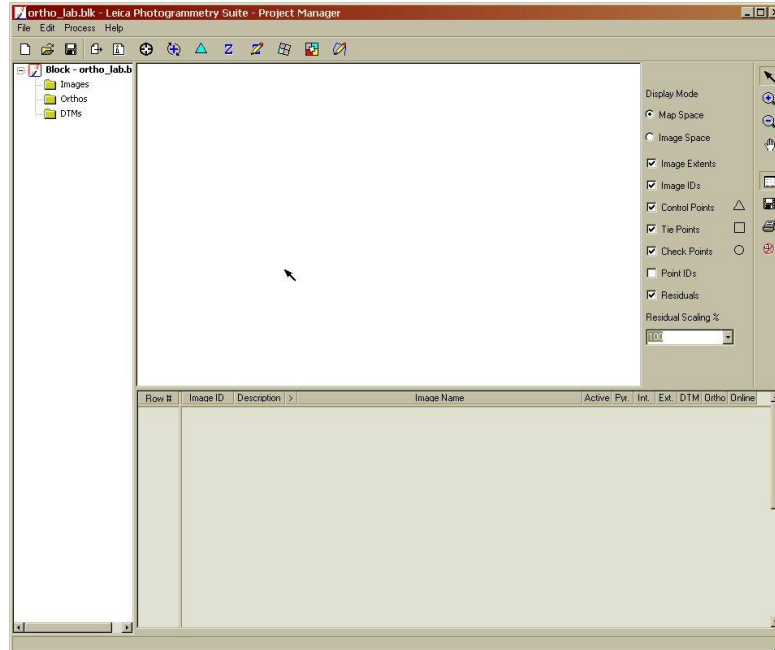
The main IMAGINE OrthoBASE dialog identifies the images being used in the block file. Each image has a series of columns associated with it.

The **Row #** column enables you to select an image specifically for use with Leica Photogrammetry Suite. For example, you may want to generate pyramid layers for one image alone.

The **Image ID** column provides a numeric identifier for each image in the block. You can change the **Image ID** if you wish.

The **>** column lets you designate the image that is currently active.

The **Image Name** column lists the directory path and the file name for each image. When the full path to the image is specified, the corresponding **Online** column is green. The **Active** column displays an **X** designating which images are going to be used in the LPS processes such as automatic tie point generation, triangulation, and orthorectification.

The final six columns' status is indicated in terms of color: green means the process is complete and accurate; red means the process is incomplete.

The **Pyr.** Column indicates the presence of pyramid layers. The **Int.** column indicates if the fiducial marks have been measured for interior orientation. The **Ext.** column indicates if the final exterior orientation parameters are complete. The DTM column if elevation data has been provided for your control points The **Ortho** column indicates if the images have been orthorectified. The **Online** column indicates if the images have a specified location.

Adding Imagery to the Block:

Now you're going to add images to the block file and define the camera model.
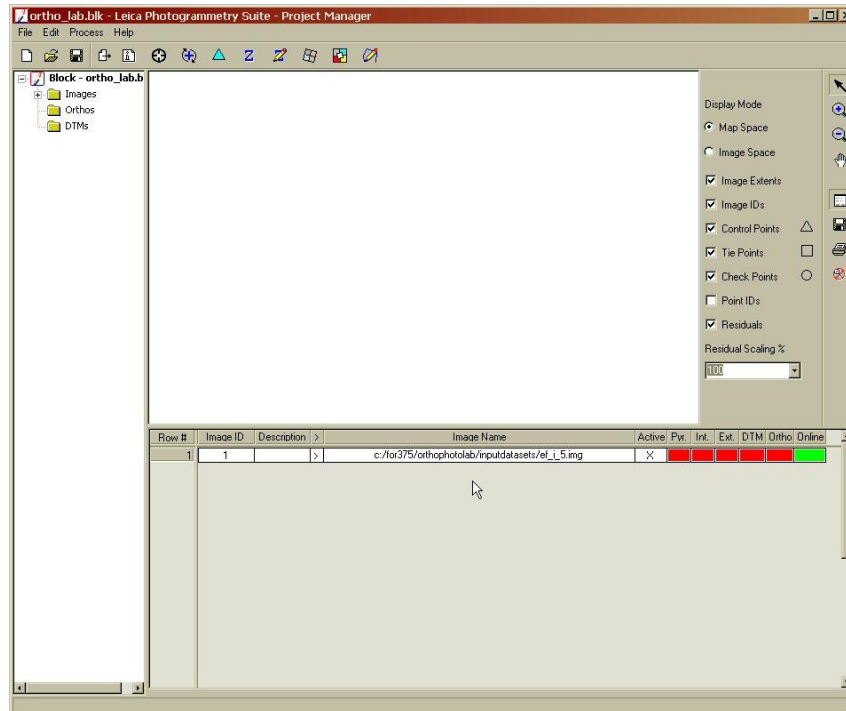
1.   Select **Edit | Add Frame** from the LPS menu bar.
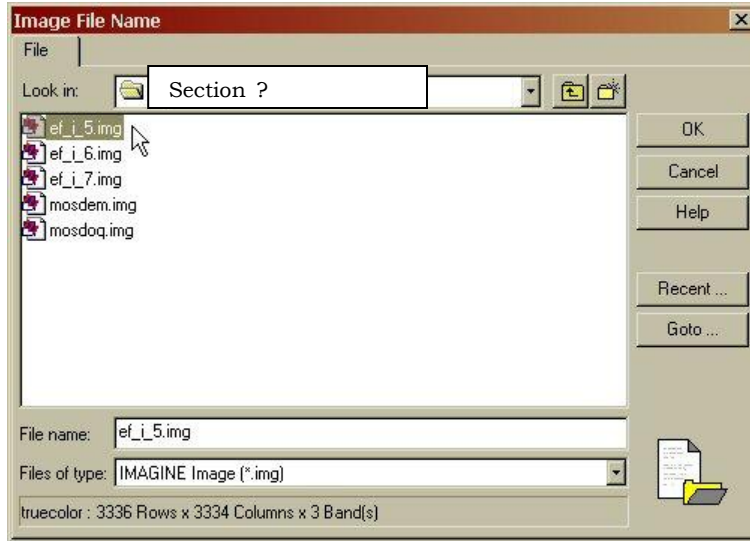
The Image File Name dialog opens.

2. Navigate to "C:\FOR_375\Section_?" and select **EF_i_5.img**.
3. Click **OK** to add the image and close the Image File Name dialog.

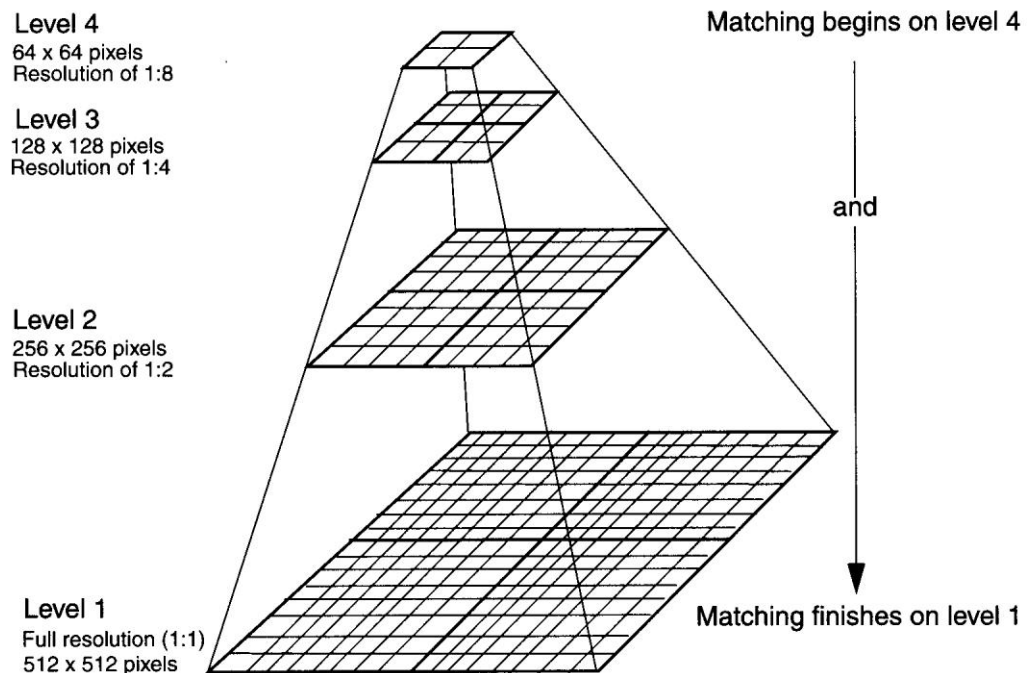The frame image file is loaded into LPS and displayed in the CellArray.

Notice that the Pyr., Int., Ext., DTM, and Ortho column status blocks are colored red. This indicates that these processes are incomplete. The Online status block is colored green which indicates that the image has a specified location.

4. Add the other two photos (ef_i_6 and ef_i_7) to the block file by repeating steps 1 − 3. Click your save icon to save your block file. You can exit LPS and return at any time now and re-open your block file. It will return you to the last point you were at before exiting (***it's a good idea to save frequently when working***).
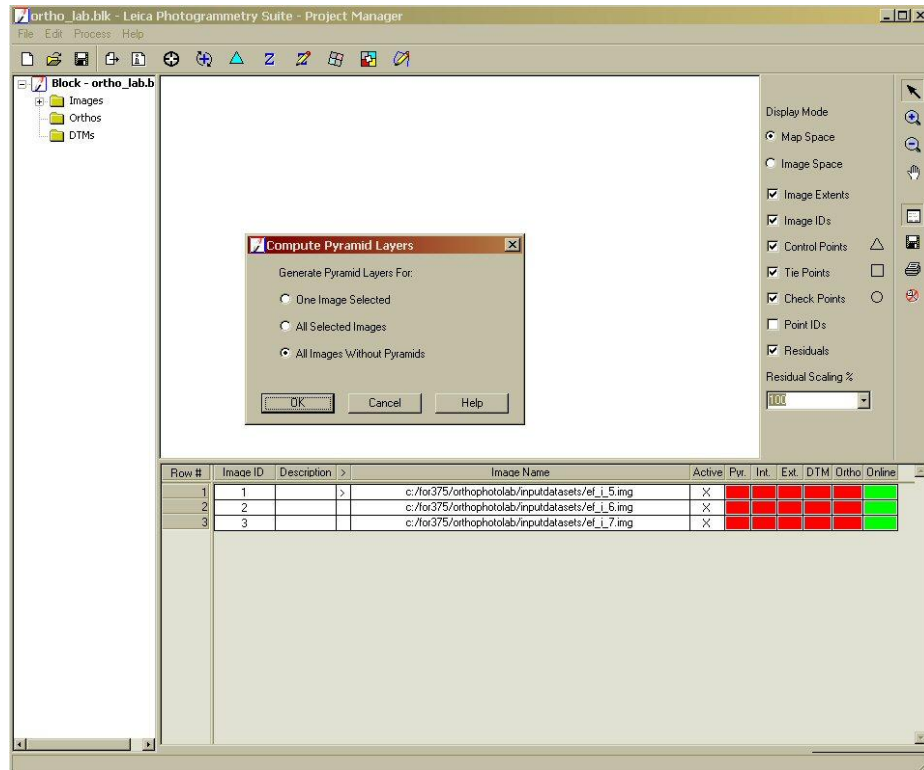
Next, you will compute pyramid layers for the images in the block file. Pyramid layers are used to optimize image display and automatic tie point collection.

Compute Pyramid Layers:

The pyramid is a data structure consisting of the same image represented several times, at a decreasing spatial resolution each time. Each level of the pyramid contains the image at a particular resolution. IMAGINE gives you the option to "pyramid" large images for faster processing in the Viewer. This option creates reduced subsampled raster layers. These can either be stored within the .img HFA file, or as a separate file with the .rrd extension, determined by Preference settings.

Level 4
64 x 64 pixels
Resolution of 1:8

Level 3
128 x 128 pixels
Resolution of 1:4

Level 2
256 x 256 pixels
Resolution of 1:2

Level 1
Full resolution (1:1)
512 x 512 pixels

Matching begins on level 4

and

Matching finishes on level 1

1. Click the **Edit** menu, and then choose the **Compute Pyramid Layers** option.

2. The Compute Pyramid Layers dialog opens. Select the "All images Without Pyramids" and Click OK. The Pyr. Boxes should turn green indicating that pyramid layers now exist for each image.

Define the Camera Model:

When you define the camera model, you provide information about the position of the fiducials, as well as the exterior orientation information of the camera that collected the images. You need to have the camera information prior to using LPS. This information can be usually be found in the camera calibration report that is provided by the company or organization that flew the site.

The photos used in this lab exercise were flown using a Zeiss model camera that had a 12" focal length.
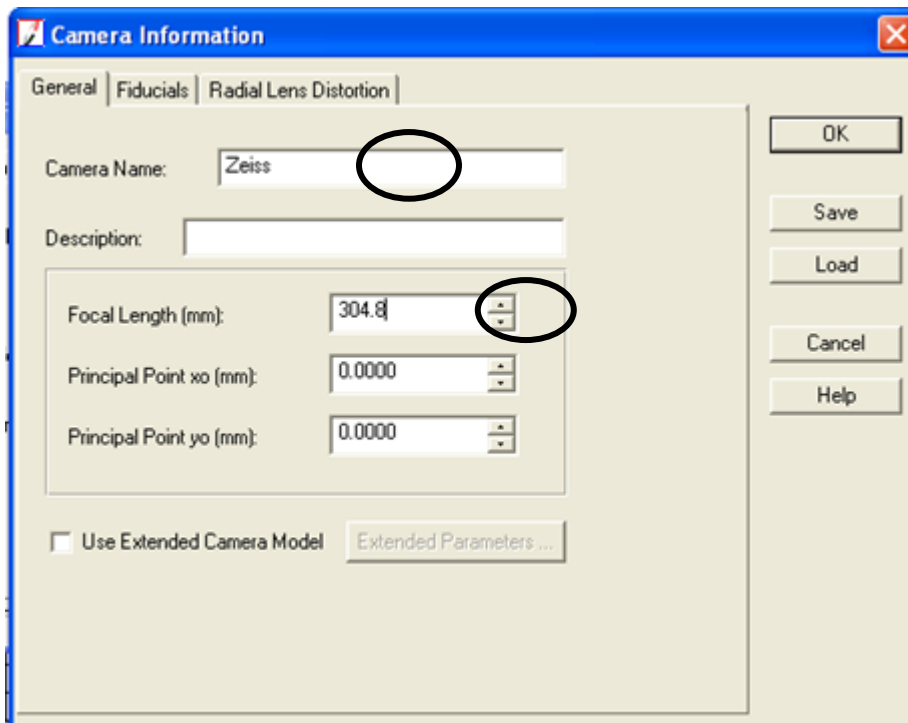
1. Select **Edit | Frame Editor** from the main IMAGINE Orthobase dialog menu bar, or click the Frame Properties icon.

The Frame Editor dialog opens, displaying information about the current image listed in the LPS CellArray, indicated with the >.
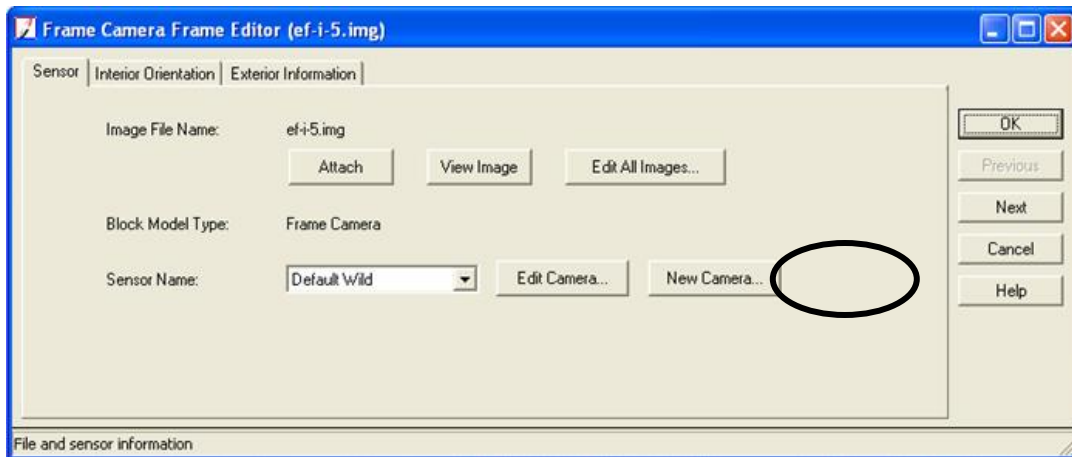
2. Next to **Sensor Name**, click the **New Camera** button.
   The Camera Information dialog opens.

3. Enter **Zeiss** in the **Camera Name** text field.

4. Enter **304.8** in the **Focal Length (mm)** number field.

   The **Principal Point xo** and **Principal Point yo** are used to indicate Principal Point offsets. This would occur when the plane tilted from vertical plane. This information would be located in the photographs' calibration report.

   We could not locate the calibration report for these photos. For this exercise, you will assume that the principal point is located in the center of the photo ("0" offset).
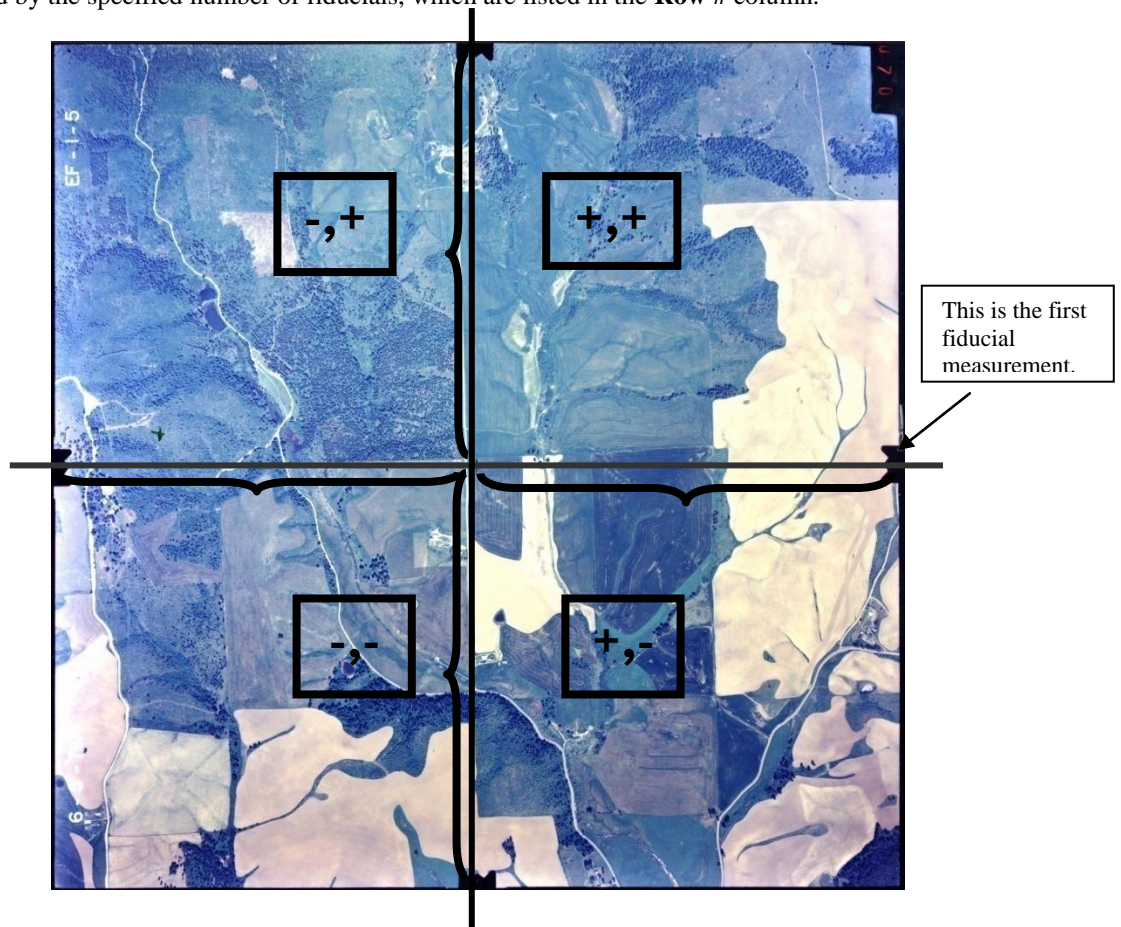
Add Fiducial Mark Locations:

1. Click the **Fiducials** tab in the Camera Information dialog.

   The options for the fiducials display.
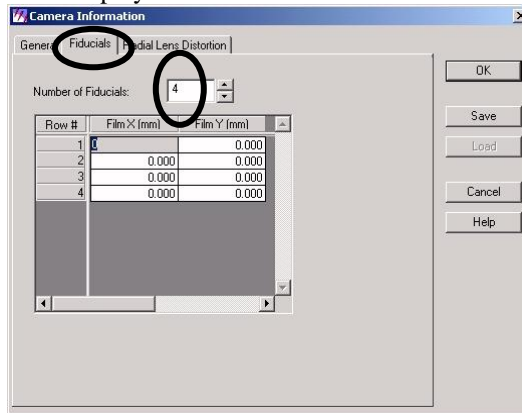
2. Determine the number of fiducial marks that are displayed on your aerial photographs and type this value into the **Number of Fiducials** number field, then press Enter. The CellArray is populated by the specified number of fiducials, which are listed in the **Row #** column.

3.

4. The location of the fiducial marks is determined by locating the fiducial marks on the photo and creating a Cartesian coordinate system with the fiducial marks depicting the x and y axis, with the

photo positioned so that North is facing up. This is illustrated in the above diagram. In this case we are providing the fiducial measurements associated with the photos that were scanned for this exercise. If you measure these distances on the photos in your packet they should be very similar.

5. Enter the following coordinates into the CellArray in this order:
1) 112.818, 0;   2) -112.818, 0;   3) 0, 112.818; 4) 0, -112.818
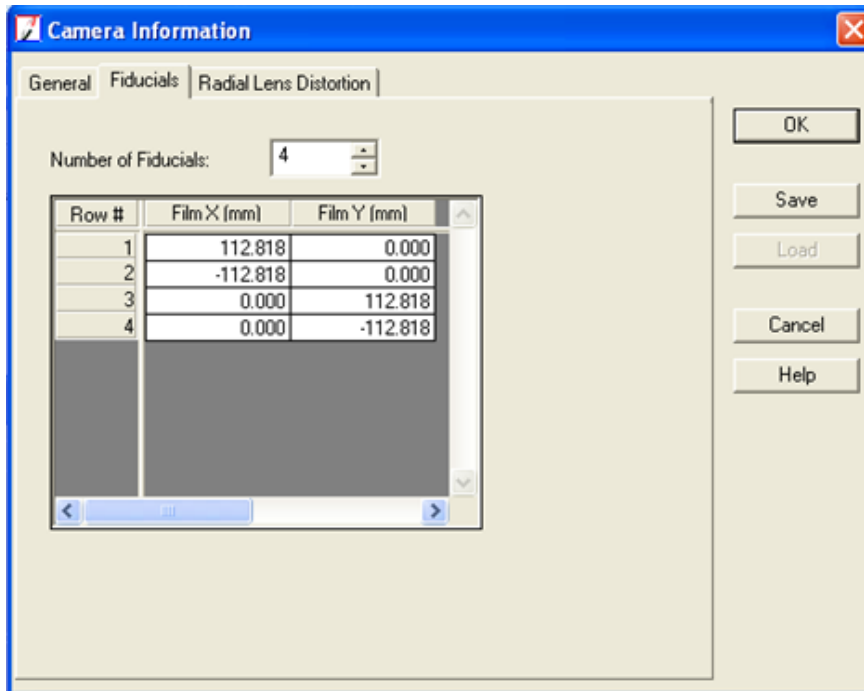
6. Click **OK** to close the Camera Information dialog. The Frame Editor dialog re-opens. If we had details from the camera manufacturer about parameters characterizing the radial lens distortion for this camera we could have entered them as well in the previous window (we do not have these details).

Measure the Fiducials of the Images

In this section, you are going to measure the fiducial marks within the photo image file.

1. Click the **Interior Orientation** tab of the Frame Editor dialog. The tools for setting up the image's interior orientation information display.
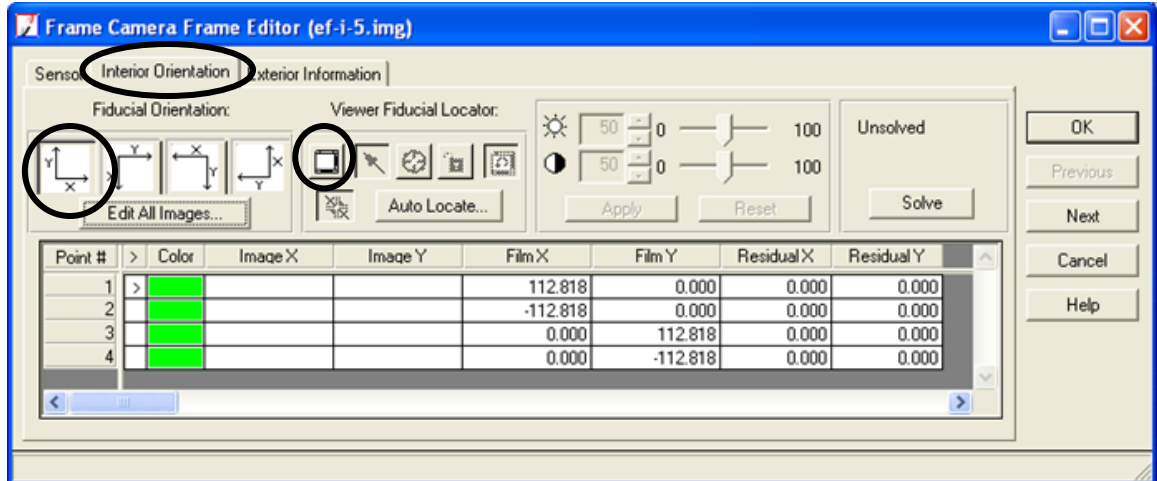
2. Make sure the first **Fiducial Orientation** icon is selected.

3. Click the Viewer icon.

A Main View opens in the main block file window, with an **Overview** that shows the entire image and a **Detail View** that shows the part of the image within the Link Cursor (small box) of the image. Any of the three views can be used for measuring the fiducials, however, it is usually easiest to select them in the **Detail View**. You can select the box, expand the size or decrease the sizes to change your view, or move the box. Become familiar with these tools.

The approximate area of the first fiducial is identified by the Link Cursor in the **Main View**, and displays in the **Detail View**.

4. Click in the center of the Link Cursor in the Over View and drag it so that the first fiducial mark listed in the CellArray (>) is in the center.

5. In the Main View, drag the Link Cursor so that the fiducial mark dot is in the center.

6. Click the Place Image Fiducial icon on the **Interior Orientation** tab.

Your cursor becomes a crosshair when placed over any one of the views. You want to use your zoom in tools to place the fiducial cross-hair as precisely as possible. Care in doing these steps will result in less work and more accurate results.

7. Measure the first fiducial by clicking in its center in the Detail View.

The fiducial point is measured and reported in **Image X** and **Image Y** coordinates, and the display automatically moves to the approximate location of the next fiducial.

Main View →

← Over View

Link Cursors

← Detail View

8. Measure the remaining fiducials using step 5 through step 7. You should notice that as you place a fiducial location the row for that fiducial mark lists the image coordinates for that point.

When all four fiducials are measured, the display returns to the first fiducial mark.

Your solution (displayed over the **Solve** button on the **Interior Orientation** tab of the Frame Editor) should usually be ½ or less the pixel size of your image. In this case the error will be greater than this, so try to attain the lowest error possible by remeasuring. To re-measure, click in the row of the **Point #** you wish to change, click the Selection tool [image], then reposition the fiducial mark in the Detail View. You can improve the positioning of the points by zooming in on the detail view and by changing the image contrast.

Question #3: What is your RMS error for each photo? (Return to this question later to answer for ef-i-6 and ef-i-7)

_____

9. Click on the Viewer icon to dismiss the views.

**Enter Exterior Orientation Information**

Exterior Orientation - This tab allows you to specify the exterior orientation parameters for your camera as they existed at the time of image capture. There are six parameters, with information regarding the status and standard deviation of each parameter.

Perspective Center (meters) - This set of parameters define the position of the perspective center at the time of image capture. They may be provided with the data set or they may be determined by LPS.

Rotation Angles(degrees) - This set of parameters define the rotation in degrees of the camera at the time of image capture. They may be provided with the data set or they may be determined by LPS.

1. Click the **Exterior Information** tab on the Frame Editor dialog.
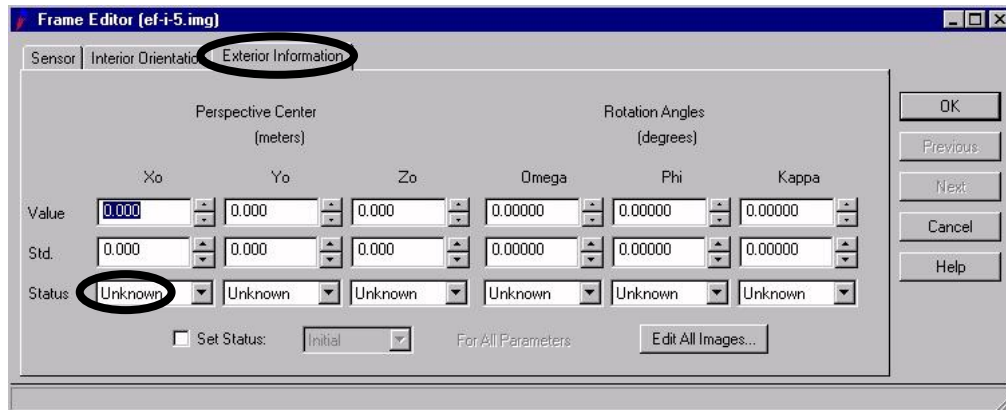
Exterior Information could not be obtained for your aerial photographs by reviewing the camera calibration report. You will have the LPS software determine this information based on a mathematical solution.

2. For all columns in the Exterior Information tab, click the **Set Status** dropdown list and choose **Unknown**.

    Now, you need to measure fiducials and define the exterior orientation for the remaining images in the block file.

3. Click on the **Sensor** tab in the Frame Editor dialog.

    This returns you to the beginning of the process. Now you will complete this process two more times, once for each remaining image in the block file (ef-i-6, ef-i-7), measuring fiducials and selecting Unknown for all columns in the exterior information tab.

4. Click the **Next** button on the Frame Editor dialog.

    The **Image File Name** on the **Sensor** tab changes to the next image, **ef-i-6**, in the LPS Cell Array.
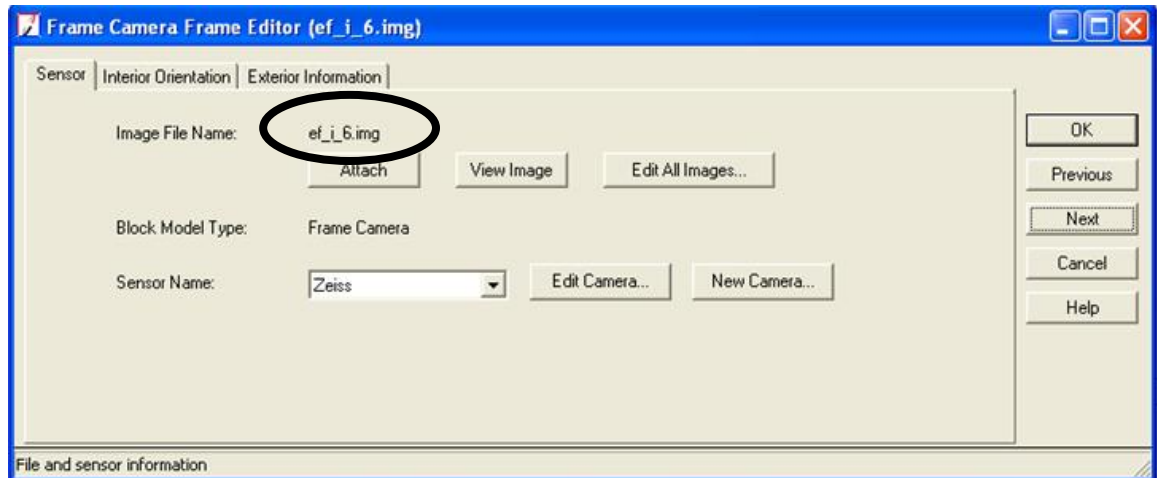
5. Note that the camera displayed, **Zeiss**, is the same as that entered for the first image.

6. Follow steps 1-9 in the **Measure Fiducials of the Images** section and steps 1-3 in the **Enter Exterior Orientation Information section.**

7. Click the **Next** button on the Frame Editor dialog and follow the same procedure as in step 6 above to enter interior and exterior information for photo **ef-i-7**.

8. Once all information has been entered in the interior and exterior orientation tabs, click **OK** to close the Frame Editor dialog. Note that the **Int.** column of the main IMAGINE OrthoBASE dialog is green, indicating that the Interior Orientation information has been specified. The Interior Orientation section of this lab is now complete.

   Be sure to **SAVE** your work by saving in the main block toolbox.

In the following section you will measure ground control points to determine the exterior orientation of your photos (entered as "Unknowns" above). You will assign a ground coordinate system to your photos through the placement of ground control points on your photos and on a DOQ that has a known ground coordinate system. Terrain variations will also be accounted for by using a DEM to determine the elevation of each control point. See the "Introduction to the Orthophoto generation exercise" for more details.

Measure Ground Control and Check Points (Completing Exterior Orientation):

Now that you have measured the fiducials and provided interior orientation of each image that makes up the block, you are ready to use the Point Measurement Tool to measure the position of ground control points and tie points in the images.

1. In the LPS project manager window Select **Edit | Point Measurement** from the main LPS dialog menu bar or click the Point Measurement icon on the LPS tool bar to open this dialog. Select the **Classic Point Measurement Tool** and select **OK.**
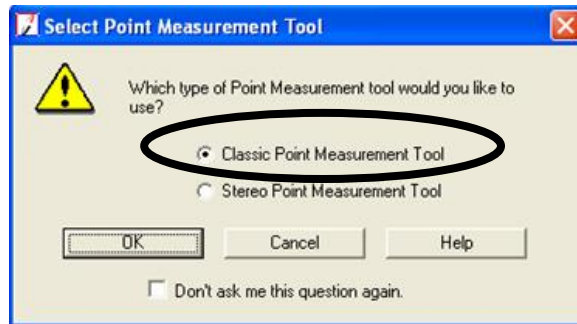
The Point Measurement Tool opens on your screen. This dialog consists of a Tool Palette, a Reference Cell Array and a File Cell Array, and six Viewers in two groups that display different views of two of the block image files. In the **Left View** you see the first image in the block file, **ef-i-5**. In the **Right View**, you see the second image in the block file, **ef-i-6**.
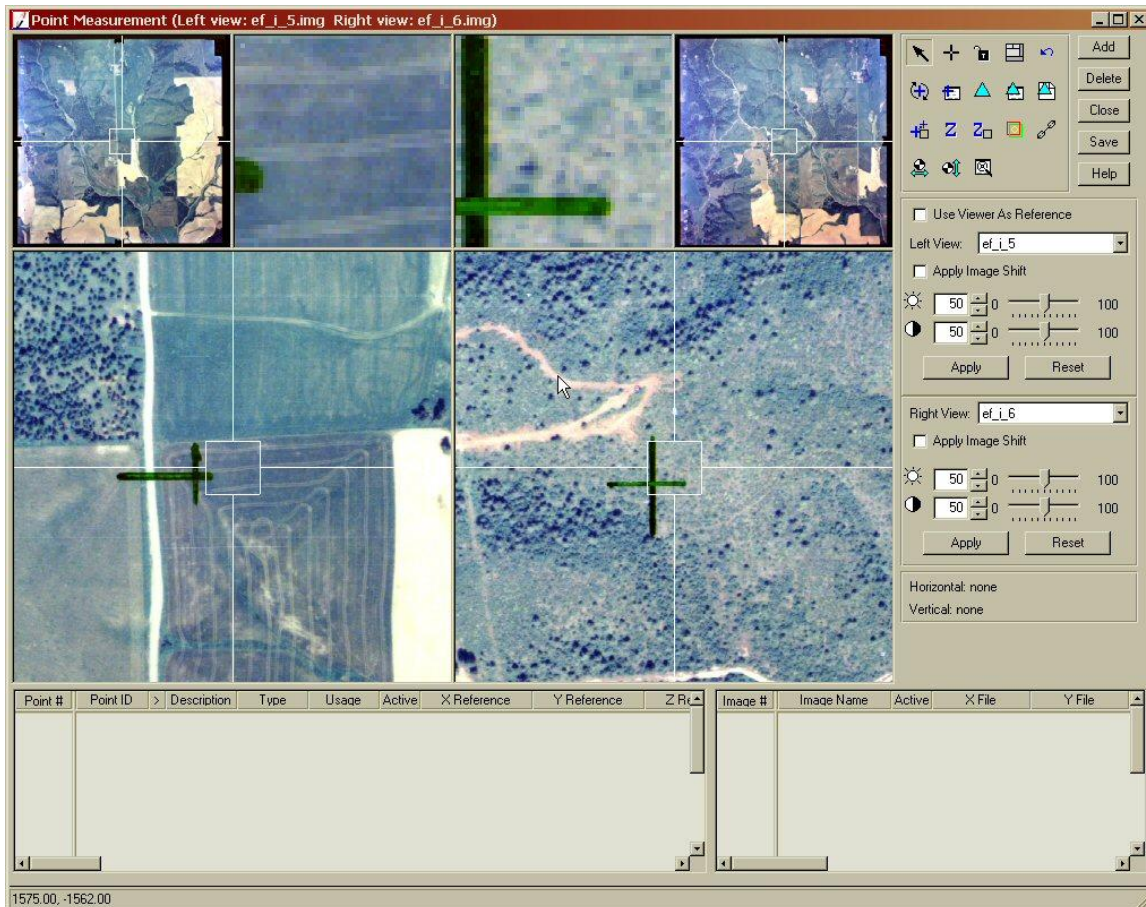
For information about the tools contained in the Point Measurement Tool Palette, see the On-Line Help.

Ground Control Points (GCP) are typically placed in areas such as road intersections, building corners, a large tree, or landmarks. You should avoid placing control points on features that vary, such as forest lines and water features. Once you have collected some well-distributed GCP's that are common to two or more images in the block file, you can perform triangulation, which will rectify the image to remove distortions relating to camera errors and photo acquisition difficulties. This orthorectification process will then produce a planimetric image that can be printed to paper and used as a map.

The next series of steps takes you through the process of collecting a GCP. You will rectify your school photos horizontally by using a digital orthophotoquad (DOQ). DOQs are black and white photos that have been geographically rectified. To remove vertical distortions from your school photos, you will use a USGS Digital Elevation Model (DEM).

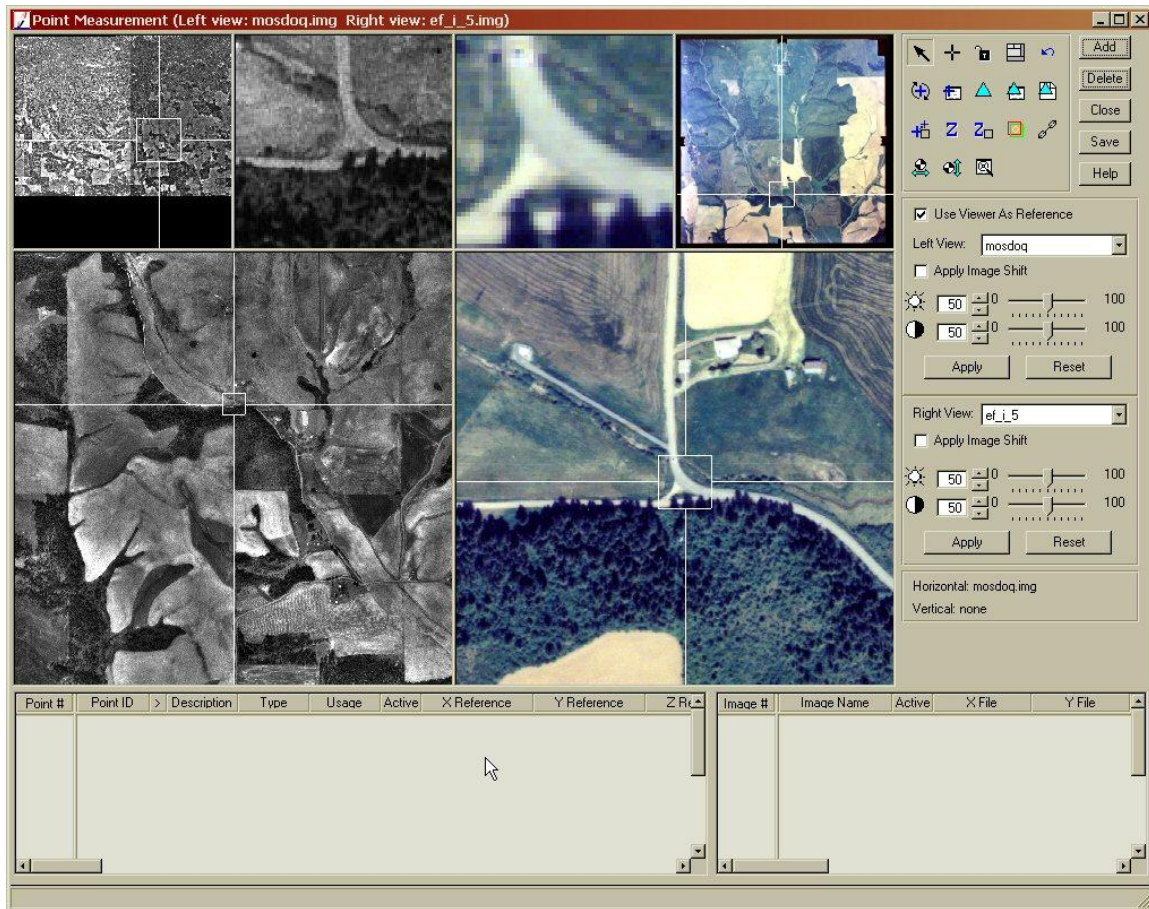1. In the Point Measurement Tool Palette, click the Horizontal Reference Source icon.

The GCP Reference Source dialog opens.
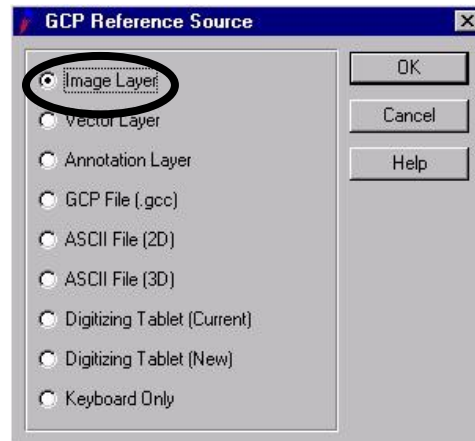
1. In the GCP Reference Source dialog, click to select the **Image Layer** option.

2. Click **OK** in the GCP Reference Source dialog. The Reference Image Layer dialog opens.

3. Navigate to "C:\FOR_375\Data_Files\Orthophoto Generation" and select the file **mosdoq.img**. This image is the Moscow Mountain DOQ.

You should notice that, although we are going to use an existing DOQ for obtaining our ground control points, other methods for obtaining these reference points exist and can be incorporated through the above step.

4. Click **OK** in the Reference Image Layer dialog. The Reference Image Layer dialog closes, and you are returned to the Point Measurement Tool dialog.
5. In the Point Measurement Tool dialog for the Left View, click the checkbox next to **Use Viewer as Reference.** The Point Measurement Tool automatically changes to display the new image, **mosdoq.img**, in the three Viewers on the left of the Point Measurement Tool. (if you get a message to create pyramid layers click OK)
6. In the Point Measurement Tool dialog, click the dropdown button by the **Right View:** text and select photo **ef-i-5.img**. Now ef-i-5 is displayed in the right three Viewers.

    You are going to obtain reference coordinates for each Ground Control Point GCP by selecting points on **mosdoq**, the reference image, that correspond to the same points on the **ef-i-5** image.

Collect GCPs:

In this next step, you are going to use screen locations on the reference image, **mosdoq**, and the first image in the block, **ef-i-5**, to collect the X and Y coordinates of the GCPs. This guide will inform you on where to locate the first GCP. You will then place at least 9 more GCPs throughout the rest of **ef-i-5**.

NOTE: LPS requires at least 3 vertical GCPs and 2 horizontal GCP's per photo. For this exercise you will locate 10 vertical GCPs and 10 horizontal GCP's per photo.

Collect point ID 1:

1. Click the **ADD** button in the Point Measurement Tool Palette.

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A row with **Point ID 1** is added to the left Reference CellArray.

2. Consult the figure on the previous page for the location of **Point ID 1** in the **mosdoq** Viewers on the left side of the Point Measurement Tool. You will need to reposition the link cursors within each Viewer to locate the road intersection on both the **mosdoq** and **ef-i-5** Viewers. You can resize the link cursors by grabbing the cursor box corners and, while holding the left mouse button, move the mouse to the desired size. Likewise, to move the entire box, grab one of the handles sticking out of the box (place cursor over the handle and click the left mouse button).

3. Once you have the cursor boxes located to the position shown in the previous figure, you are ready to collect the control point.

4. Click the Create Point icon.

5. Move the cursor into the Detail View containing the reference image, mosdoq, and click to select the intersection. A control point is placed on the intersection and labeled **1**. The Reference Cell Array updates to include the **X Reference** and **Y Reference** coordinates of the reference image, **mosdoq**.

6. Check your control point coordinates. They should be within 10m of the following table:

Point ID	X Reference	Y Reference
1	516039.882	5179836.635

7. If your coordinates do not approximate (within 10 meters) those listed in step 6 above, type the correct coordinates in the Reference CellArray or reposition the control point while grabbing it with the left mouse button. Press enter on the keyboard if you typed the coordinates into the CellArray.

Now, you are going to collect the point on the block image, **ef-i-5**.

8. Consult the previous figure for the location of **Point ID 1** in the **ef-i-5** Viewers on the right side of the Point Measurement Tool. This location will be the same road intersection location as in the **Point ID 1** in the **mosdoq** Viewer.

    When you have found the road intersection and centered it in the Viewers, you are ready to collect the control point.

9. Click the Create Point icon.

10. Move the cursor into the Detail View containing the first image in the block file, and click to select the intersection. A control point is placed on the intersection and labeled **1**. The File CellArray updates to include the **ef-i-5** image, and the **X File** and **Y File** coordinates are updated.

11. Check your control point coordinates. They should approximate those in the following table:

Image Name	X File	Y File
ef-i-5	**1652.884**	**2508.484**

12. If your coordinates do not approximate (within six pixels) those listed in step 11 above, type the correct coordinates in the Reference CellArray or reposition the control point while grabbing it with the left mouse button. Press enter on the keyboard if you typed the coordinates into the CellArray.

Collect point ID 2 – 10:

1. Follow steps 1 – 12 (in the collect Point ID 1 section) to collect 9 more GCPs. Choose your points with care. Spread the points out so that they are not located in the same area. Where does most of the distortion fall within an air photo? These are areas that you will need to place a GCP so that the photo can be shifted and repositioned into its proper spatial location.

   Your Moscow Mountain DOQ was captured in 1992. What year were your air photos taken? This will cause some difficulties in finding distinguishable points in both the reference image and the block file image. Choose road intersections, buildings, and other well-defined features for you GCPs. ******* It would be **smart** to mark all your GCP's with its corresponding point number on your air photo (ef-i-5) for future reference. This will also allow you to reference how well you've distributed points around your photo.

   NOTE: REMEMBER TO PRESS THE <u>ADD</u> BUTTON TO SELECT THE NEXT GCP, OTHERWISE YOU WILL MOVE THE PREVIOUS GCP TO A DIFFERENT LOCATION. This is a COMMON error made during these steps of the lab.

2. After collecting two GCPs, IMAGINE OrthoBASE provides some automatic functions to enable you to select ground control points more rapidly. Activate the Automatic (x,y) Drive function by clicking the Automatic (x,y) Drive icon.


   The icon changes to:

   This icon allows IMAGINE OrthoBASE to approximate the position of the GCP in the block image file, **ef-i-5**, based on the position in the reference image, **mosdoq**.

   Continue collecting the rest of your 10 total GCPs. Click to save frequently during this process.

3. After collecting all 10 GCPs for ef-i-5 photo, save your work by click the **Save** button on the Point Measurement Toolbox.
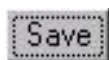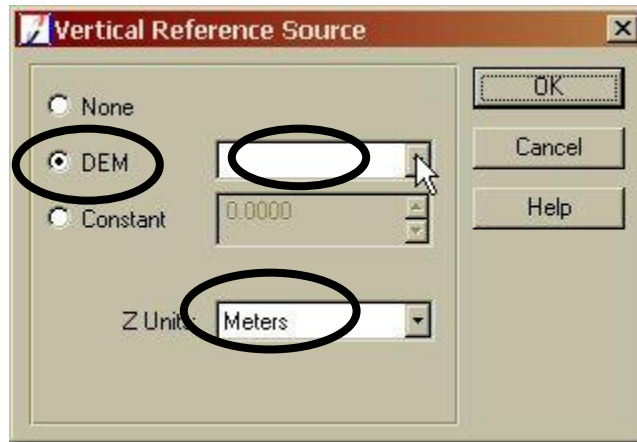
Set the Vertical Reference Source:

To provide Z, or elevation values for all of the reference control points you selected in the reference image, **mosdoq**, you are going to specify a digital elevation model (DEM), **mosdem.img**, which contains height information.

1. Click the Vertical Reference Source icon.

The Vertical Reference Source dialog opens, in which you will select the DEM that is going to supply height information.

2. Click to **Find DEM** option.

3. Navigate to "C:\FOR_375\Data_Files\Orthophoto Generation" directory and select the DEM file **mosdem.img**.

4. Click **OK** in the File Chooser dialog. The DEM file you selected is shown in the **DEM** section of the Vertical Reference Source dialog.

5. Click **OK** in the Vertical Reference Source dialog.

6. Within the Reference CellArray, right-click in the **Point #** column within the reference CellArray and select the **Select All** option.
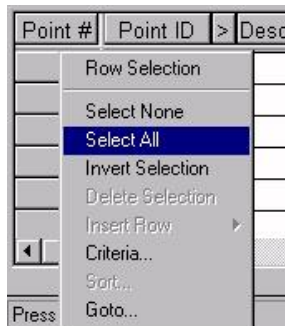
7. Click on the Update Z Values on Selected Points icon.

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Dismiss any error message windows, there might be two of them.

The Z Values of all the reference points are updated in the Reference CellArray based on the values in the DEM you selected, **mosdem**.

ce	Y Reference	Z Reference
.871	5179458.009	871.583
.929	5180688.781	838.579
.609	5179911.209	855.013
.311	5180586.169	868.118
.613	5180717.236	912.836
.550	5179382.944	827.820

8. Right-click in the **Point #** column and choose **Select None**.
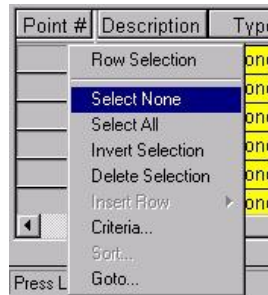
Another function of the LPS software is the automatic Z value update. **Click** the **Automatic Z Value icon** in the Point Measurement Tool Palette.

The icon then changes to the following:

indicating that the Z value will be updated automatically each time you choose a point.

Collect Ground Control Points for EF-I-6:

In this section, you will collect GCPs for the next block image file (EF-I-6). You first must collect points based on those you have already collected on **EF-I-5**. On your photo, locate all GCPs that you collected on **EF-I-5** that can be located on **EF-I-6**. Remember, the photos overlap, so many GCP's (but not all) will be common to other photos in your block. GCP #1 (the first road intersection point) is located on both photos. If you have placed the individual control points on your **EF-I-5** photo from your lab packet, you can simply

overlay **EF-I-6** on it to see which control points fall on both photos. This will assist you in quickly finding them on the digital version of your images.
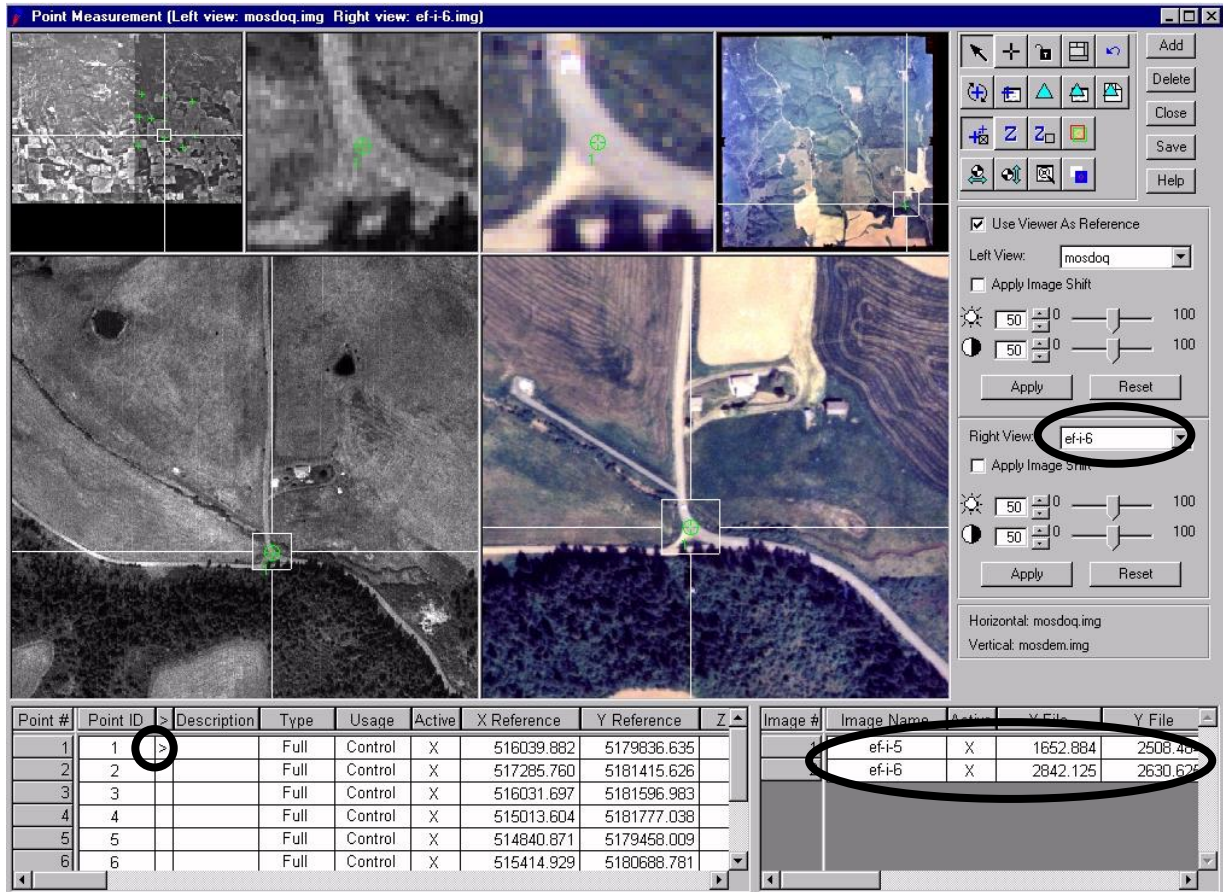
1. Click the dropdown list for the **Right View** and select the block image **EF-I-6**. The **EF-I-6** will appear in the **Right Viewers**.

2. In the Reference CellArray, select **Point ID #1** by clicking the selector field, **>**, for this point. **Mosdoq** automatically changes position in the Viewers to show **Point ID 1**.

3. Move the Link Cursor in the Viewers displaying **EF-I-6** until you can see the road intersection.

4. Click the Create Point icon in the Point Measurement Tool Palette

    **Note, do not click "Add" as before because the control point on your reference image has already been located. You only need to click "Add" when you are adding a new control point on your Reference Image.

5. Place the point in the Detail View for **EF-I-6**, displayed in the right-hand Viewers. A point is placed in the Detail View and labeled **1** on photo EF-I-6.

6. Check your control point coordinates. They should approximate the X & Y values in the following table:

Image Name	X File	Y File
ef-i-6	**2842.125**	**2630.625**

Note: The Image CellArray now shows two rows indicating two GCP points, located on both **EF-I-5** and **EF-I-6**, for the single GCP #1 of the reference image.

7. Continue selecting other GCPs within the Reference CellArray that correspond to both **EF-I-5** and **EF-I-6**. Follow the same procedures as listed in 1-5 above.

8. Once you have identified all GCPs that are located on both **EF-I-5** and **EF-I-6**, collect additional GCPs for the **EF-I-6** image in areas that are **not located on EF-I-5**. For these points you will need to click "Add" to add new control points on your left reference image. Following the previous steps on collecting GCPs, collect a combined total of **10 GCPs** for **EF-I-6**. Remember to mark and number these GCPs on your **EF-I-6** photo. Also be sure to distribute your points around the edges of your photo.

Collect Ground Control Points for EF-I-7:

Next, you will collect GCPs for the next block image file (**EF-I-7**). You first must collect points based on those you have already collected in **EF-I-6**. On your photo, locate all GCPs that you collected in **EF-I-6** that can be located on **EF-I-7**.

1. Click the dropdown list in the **Right View Tools** and select the block image **EF-I-7**. The **EF-I-7** will appear in the **Right Viewers**.

2. In the Reference CellArray, select a **Point ID #** that is common to both **EF-I-6** and **EF-I-7** by clicking the selector field, **>**, for this point. **Mosdoq** automatically changes position in the Viewers to show the **Point ID**.

3. Move the Link Cursor in the Viewers displaying **EF-I-7** until you can see the same location as in the Reference Viewer.

4. Click the Create Point icon in the Point Measurement Tool Palette.

5. Click the approximate point Detail View for **EF-I-7**, displayed in the right three Viewers. A point is placed in the Detail View and labeled.

6. Continue selecting and locating GCPs that correspond to both **EF-I-6** and **EF-I-7**.

7. Once you have identified all GCPs that are located within both **EF-I-6** and **EF-I-7**, collect additional GCPs within the **EF-I-7** image in areas that are **not located with either EF-I-5 or EF-I-6**. Following the previous steps on collecting GCPs, collect a combined total of **10 GCPs** for **EF-I-7**. Remember to mark and number these GCPs on your **EF-I-7** photo.

8. When you have completed collecting GCPs on the **EF-I-7** image, click the **Save** button in the Point Measurement Tool Palette.
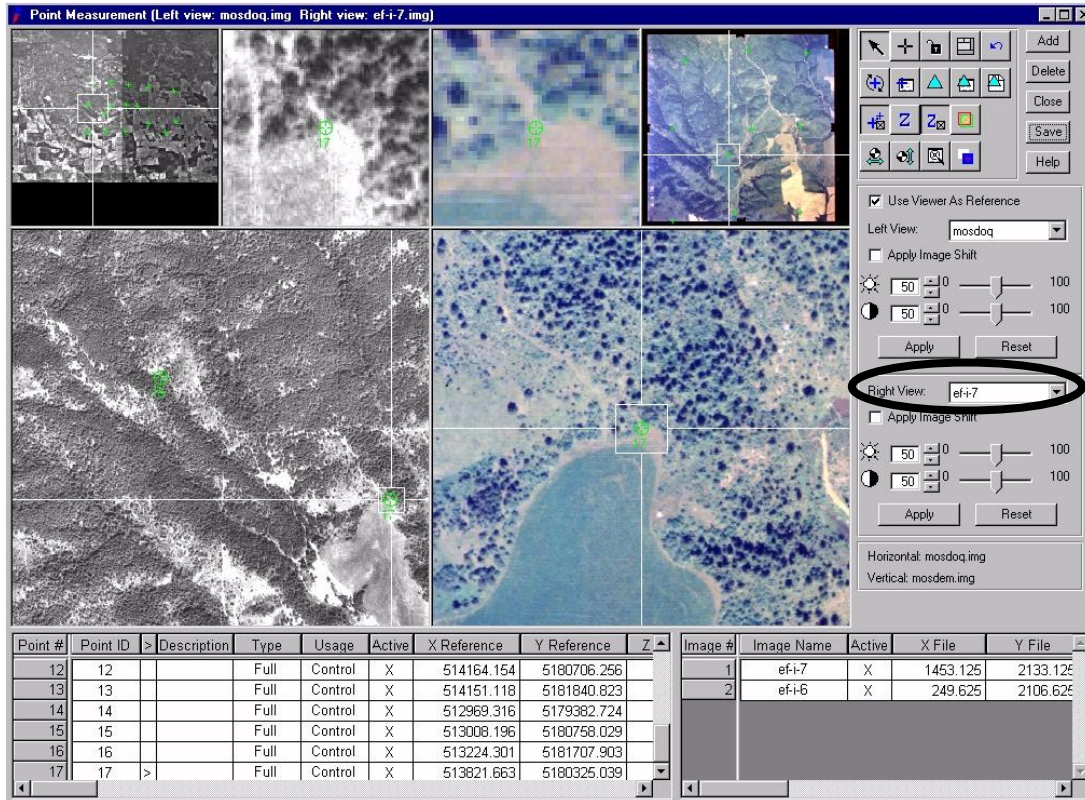
Set Type and Usage:

Up until this point, the **Type** and **Usage** for each of the control points has been set to **None** and **Tie**, respectively. Follow the steps below for a quick application of new classes of **Type** and **Usage** with LPS's Formula dialog.

The **Type column** indicates the type of point displayed in the row. The options for this field are:

Full: These are control or check points with X, Y, and Z coordinates.

Horizontal: These are control or check points with X and Y coordinates. The Z coordinate is unknown, and can be estimated or ignored during triangulation.

Vertical: These are control or check points with Z coordinates. The X and Y coordinates are unknown, and can be estimated or ignored during triangulation.

The **Usage column** displays how the point is used in triangulation and orthorectification. The options for this field are:
Control: These points are used as control points during triangulation.

Check: These points are used to independently verify the quality of a triangulation.

Tie: These points indicate the position of ground points appearing in the overlapping areas of two or more images. The X, Y, Z coordinates are determined by triangulation. These image points can be collected manually, or automatically by selecting Process | Autotie from the LPS menu bar.

1. Left-click the title bar of the column labeled **Type** to select the entire column.

2. Right-click to access the **Column Options** menu, then select **Formula**.
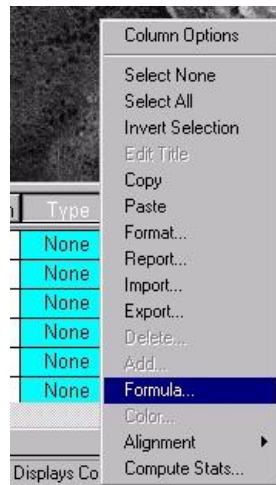
The Formula dialog opens.
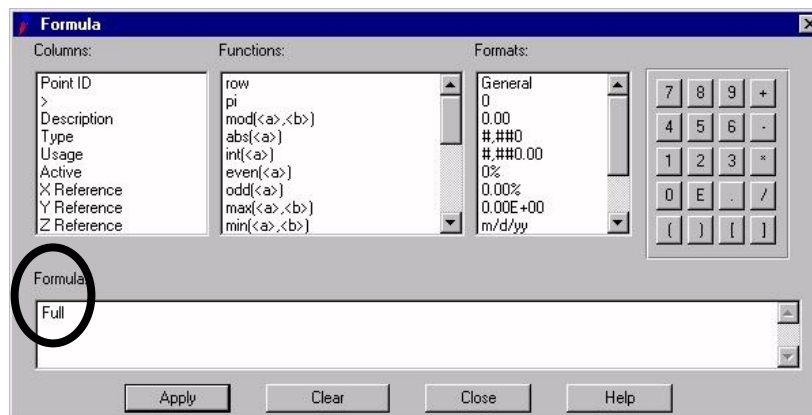
3. In the **Formula** section of the Formula dialog, type **Full**.

4. Click **Apply** in the Formula dialog. All the points' **Type** are revised to indicate **Full**.

5. Click **Close** in the Formula dialog.

6. Left-click in the column labeled **Usage** to select the entire column.
7. Right-click to access the **Column Options** menu, then select **Formula**.

8. In the **Formula** section of the Formula dialog, type **Control**.

9. Click **Apply** in the Formula dialog. All of the points' **Usage** are revised to indicate **Control**.

10. Click **Close** in the Formula dialog.

11. Right-click in the **Usage** column to access the Column Options menu, then choose **Select None**.

When you are finished, your CellArray should look the one below.

on	Type	Usage	Active
	Full	Control	X
	Full	Control	X
	Full	Control	X
	Full	Control	X
	Full	Control	X
	Full	Control	X

12. In the Point Measurement Tool Palette, click the **Save** button.

Perform Automatic Tie Point Collection:

The tie point collection process measures the image coordinate positions of tie points, which are presented in two or more overlapping images. These points are used to "tie" each of the photos together and establish coordinate relationships between the photos.

1. In the Point Measurement Tool, click the Automatic Tie Point Collection Properties icon.

The Automatic Tie Point Generation Properties dialog opens.
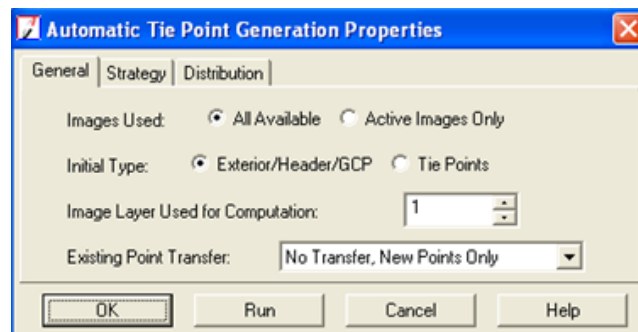
2. Check to confirm that the **Images Used** option is set to **All available**.
3. Check to confirm that the **Initial Type** option is set to **Exterior/Header/GCP**.
4. Check to confirm that the **Image Layer Used for Computations** is set to 1.
5. Check to confirm that the **Existing Point Transfer** is set to **No transfer, New Points Only**
6. Click the **Strategy** tab at the top of the window.
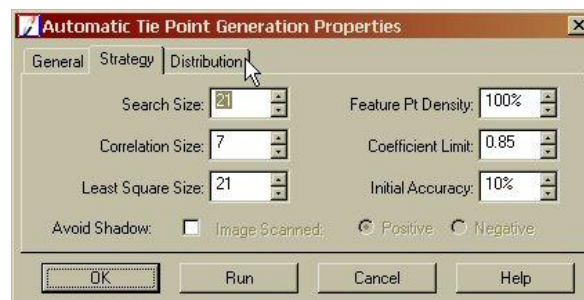
7. **Set Search Size** to 21; **Correlation Size** to 7; **Least Square Size** to 21; **Feature Pt. Density** to 100%; **Coefficient Limit** to 0.85; and **Initial Accuracy** to 10% - as shown above. Then click the Distribution tab at the top of the window.
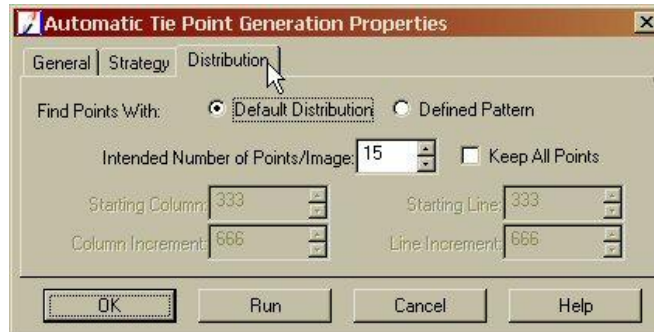
8. Click to use the **Default Distribution**. Click in the **Intended Number of Points Per Image** field and type **15**, then press Enter. The actual number of points generated by auto tie is greater than or less than 15. The number depends, in part, on the amount of overlap between the images.

9. Check to confirm that the **Keep All Points** options is off (unchecked).

10. Click the **Run** button in the Automatic Tie Point Generation Properties dialog.

    Leica Photogrammetry Suite starts the automatic tie point generation process, indicated by a progress bar, and displays the tie points in the Point Measurement dialog when complete. The tie points have the **Type** designation **None**, and the **Usage** designation **Tie**. They are added to the Reference CellArray (left side) with the corresponding **X File** and **Y File** values in the File CellArray (right side).

11. Review the **Auto Tie Summary**, then press **Close.**

Check Tie Point Accuracy:

You should always check several of the tie points to ensure accuracy. If a point is not as accurate as you would like, you can always adjust it with the Select Point tool or delete it by selecting the row in the CellArray and clicking the **Delete** button. Display a pair of photos in the two viewers (either EF-I-5 and 6, or 6 and 7).

1. In the Reference CellArray, click the scroll bar and scroll to any tie point.

2. Click in the > column to display the tie point. In the Image cell array it will indicate which two photos the tie point falls in. By definition, the tie points fall in areas within the overlap of our photos.

    The point displays in the Viewers. Does this appear to be an acceptable tie point? If you look closely at both photos, does the tie point fall in exactly the same location?

3. Click in the > column of other Point IDs to see where tie points were placed.

    NOTE: Since all tie points are not common to all images, there will be cases where the displayed images do not have corresponding tie points. In such cases, verify the tie point by opening a different adjacent image in one of the Viewers. To do so, use the **Right View** dropdown list.

4. If the position of a tie point needs to be adjusted, click the Select point icon and move it in the Detail View.


5. When you are finished, click the **Save** button.

6. Click the **Close** button to close the **Point Measurement** dialog. You are returned to the main IMAGINE OrthoBASE dialog.

Perform Aerial Triangulation:

Now that you have obtained control and tie points, LPS has all the information it needs to perform aerial triangulation. This step in the process establishes the mathematical relationship between the images that make up the block file.

1. From the **Edit** menu of the main LPS dialog, select **Triangulation Properties**.

    The Aerial Triangulation dialog opens.
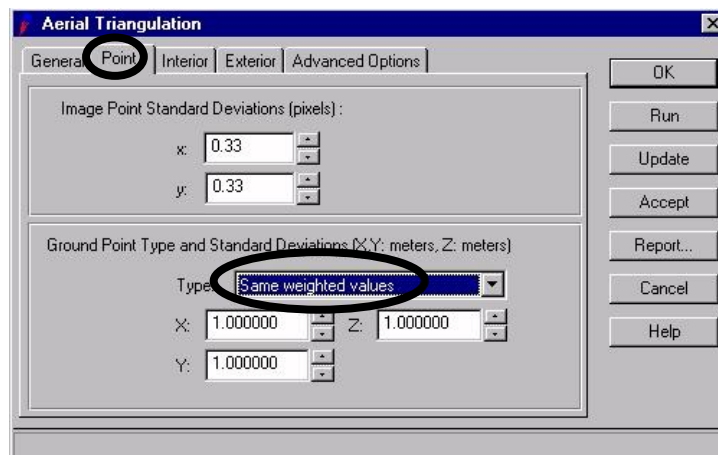
2. Click the **Point** tab in the Aerial Triangulation dialog.

    The **Point** options display. These control the statistical weights assigned to the GCP parameters. These are commonly reflected by the precision of the GCPs (i.e., the reference source).

3. In the **GCP Type and Standard Deviations** section, click the **Type** dropdown list and select **Same Weighted Values**.

4. Click the **Run** button to run the aerial triangulation.

    A Triangulation Summary dialog is generated and opened.
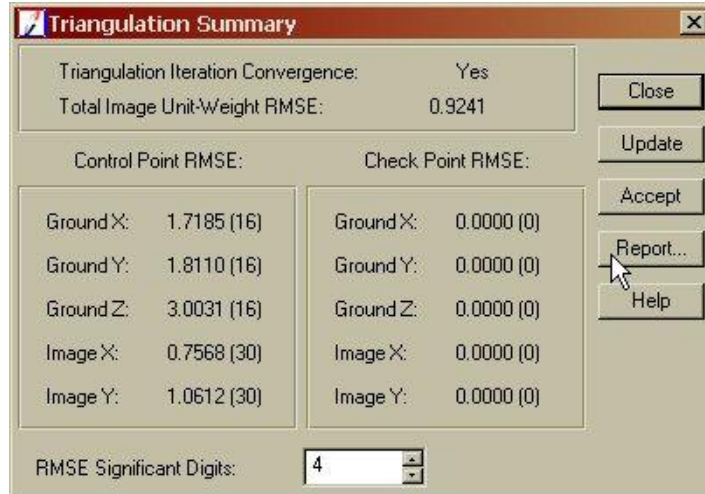
Find Information in the Triangulation Report:

You will now consult the Triangulation Report for more detailed numbers corresponding to the triangulation. You can save the report as a text file for future reference.

1. In the Triangulation Summary dialog, click the **Report** button.
2. Resize the Triangulation report so that it is all visible in the window

The Triangulation Report opens. Scroll down and look over the report.
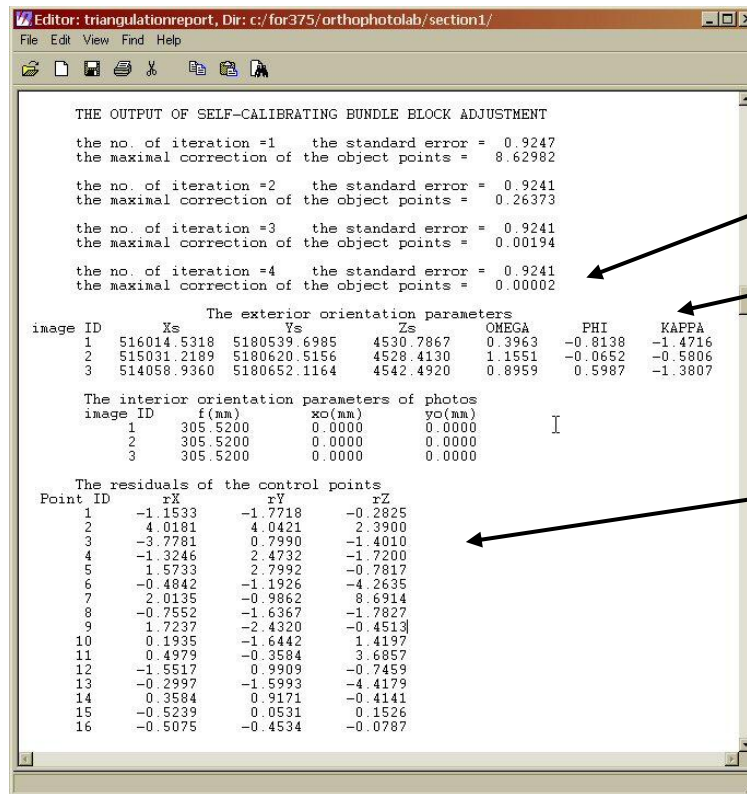
The standard error of the last iteration is the most important

The exterior orientation parameters are reported here

Control and check point residuals are reported here.

Check the Results:

1. Scroll down until you reach **The Output of Self-calibrating Bundle Block Adjustment** section of the report.

2. Note the **standard error** of **iteration** number in your report. This value is the standard deviation of unit weight, and measures the global quality of that iteration.

3. Note the **exterior orientation parameters**. These are the exterior orientation parameters associated with each image in the block file. Remember we did not have this information regarding the camera/aircraft orientation at time of acquisition. It has now been computed for us.

4. Note the **residuals of the control points**. The control X, Y, and Z residuals define the precision quality in both the average residual and the geometric mean residual.

5. Scroll down to the **residuals of image points** section of the Triangulation Report. These are the photo or image coordinates residuals. They can be used to determine the less accurate points. Some of these points may have large residuals.

6. When you are finished viewing the Triangulation Report, ***save it in your directory as a txt file***, print the page with the details shows on page 36 above and then select **File | Close**. You will be turning in the report as part of your grade!!! *** The entire report is very long and you do not need to print the entire report out – just the page with the details shown on page 36 (Output of the self-calibrating bundle block adjustment; The exterior orientation parameters; The internal orientation parameters of each photo; and The residuals of the control points. This may require printing out two pages.)

Update the Exterior Orientation:

1. In the Triangulation Summary dialog, click the **Update** button to update the exterior orientation parameters. This replaces the exterior orientation parameters that were not specified during the measurement of fiducials with the exterior orientation computed by LPS based on control and tie points in the images making up the block file.

2. Click the **Close** button to close the Triangulation Summary dialog. In the Aerial Triangulation dialog, click the **Accept** button to accept the triangulation parameters.

3. Click **OK** in the Aerial Triangulation dialog to close it. The main LPS dialog is updated to reflect the completion of the exterior orientation step. Notice that the **Ext.** column is now green.

View Control Point and Tie Point Distribution over the Block:

1. In the main block file project manager, click on the **Map Space** icon and you can now display the distribution of your control points and tie points over the block of three photos. You can also visually display the residuals for each control point. You can also exaggerate the residual scaling in the drop down menu **Residual Scaling %**. This allows you to visualize the direction and extent of the residual completed by the mathematical fit. Turn on all options on the right except for **Image Space**. ***Print this out to include with your final lab report (see printer icon on right side)***.

Orthorectify the Imagery:

The next step creates orthorectified images of your block file images. Orthorectified images have fewer relief displacements and geometric errors than non-orthorectified images, and thus are considered more accurate and useful for any kind of mapping. The orthorectified images display objects in their real-world X, Y, and Z positions.

1. In the main Leica Photogrammetry Suite dialog, click the Ortho Resampling icon. The Ortho Resampling dialog opens.
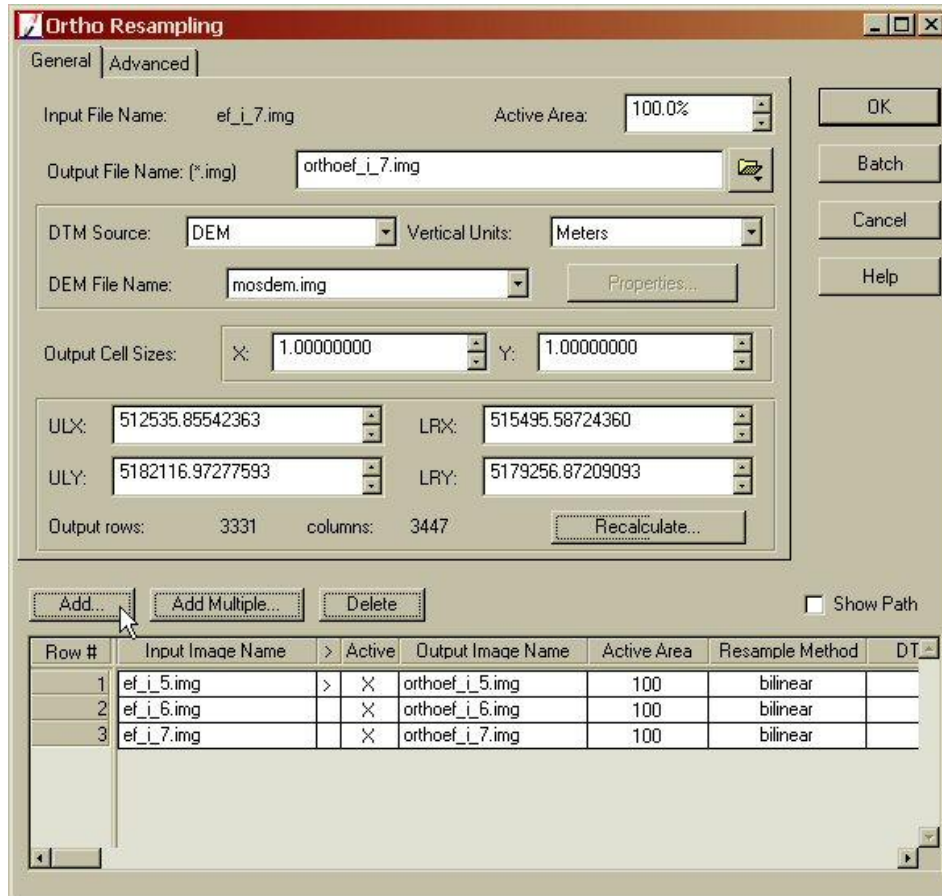
2. Click to **Add** each of your three input images and provide consistent output images names (as above). Be sure your output images are written into your working directory.

3. Make sure the DTM source is set to DEM. Select **mosdem.img** for the DEM File Name.

4. Confirm that the **Vertical Units** are set to **Meters**.

5. Click the **Advanced** tab and **Resample Method** dropdown list and select **bilinear interpolation**.

6. Back in the **General** tab click in the **Output Cell Sizes** section and change the **X** and the **Y** values to **1.0**.

7. Click **OK** in the Ortho Resampling dialog. A status dialog opens, tracking the ortho resampling process.

8. When the status dialog is 100% complete, click the **OK** button to dismiss it.

Check the Ortho Resampled Images:

Now that the images have been ortho resampled, you can check how well they fit together in a Viewer.

1. From the main ERDAS IMAGINE tool bar, click the Viewer icon.

2. A Viewer opens in the workspace. Click the Open File icon to access the Select Layer To Add dialog.

3. Navigate to your directory where the orthorectified images were saved.

4. Click to select the your **orthoef-i-5.img** image.

5. Click the **Raster Options** tab.

6. Deselect the **Clear Display** option.

7. Click to select the **Fit to Frame** and **Background Transparent** options. Click **OK** in the Select Layer To Add dialog.

8. Repeat step 2. Through 8. in the same Viewer, selecting the files **orthoef-i-6.img** and **orthoef-i-7.img**. The images are displayed in the Viewer. You can see where they overlap.

9. If you wish (and you can locate the file within your FOR375 directories), you can also bring in the DRG we used in the previous terrain analysis lab to view in conjunction with your new digital orthophoto's.
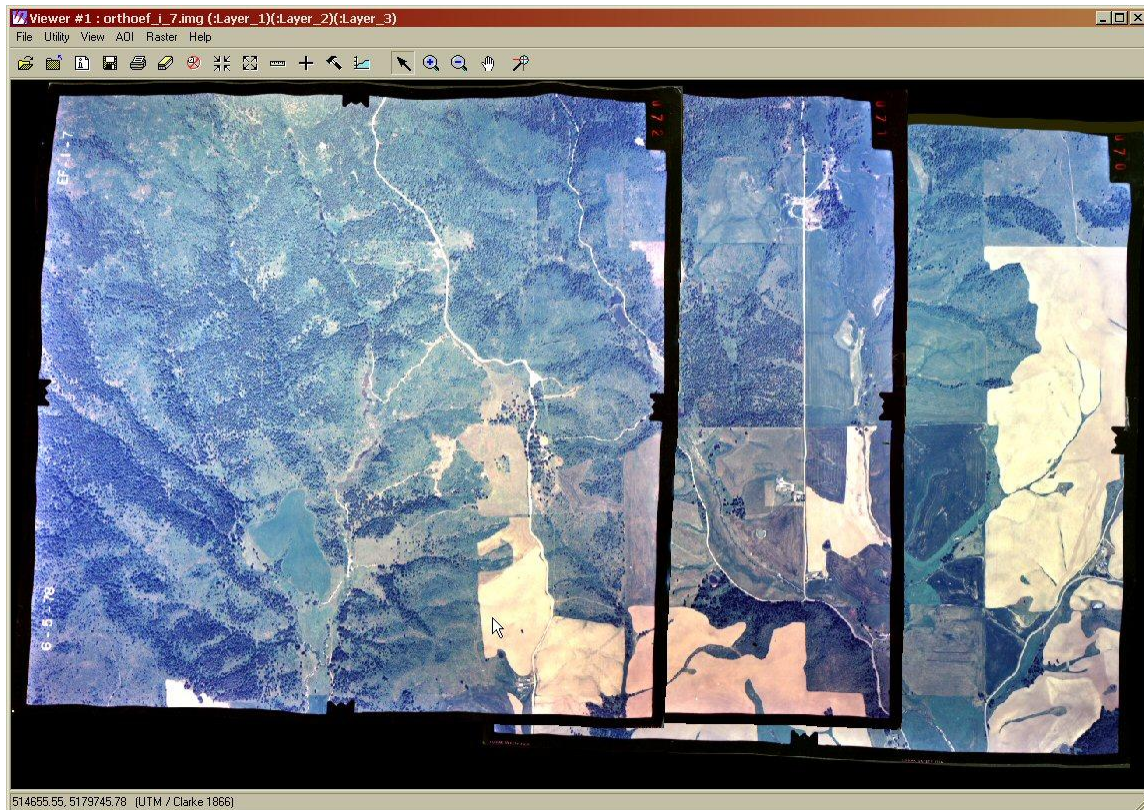
Magnify areas of Overlap:

Now, you can check the areas of overlap to see how well IMAGINE OrhtoBASE orthorectified the images. Take special note of the features such as roads, rivers, and parcels of land.

1. In the Viewer, click the Zoom In Icon.

2. Click on an area in the Viewer where two of the images obviously overlap.

3. Apply the Zoom In tool as many times as necessary to see the portion of overlap clearly in the Viewer. You can see that LPS successfully put images into the same reference coordinate space (notice the coordinate displayed in the lower left hand corner as you move the cursor around the image).

Use the Swipe Tool:

You can use the Swipe utility to see how well the images overlap.

1. Click the **Utility** menu on the Viewer menu bar. Choose **Swipe**.

The Viewer Swipe dialog opens.
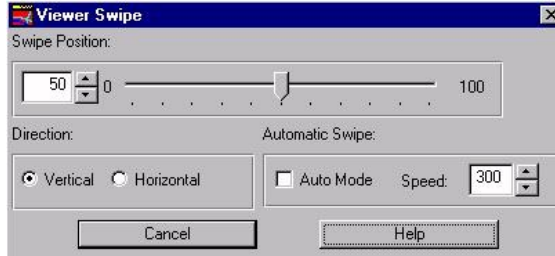
2. Right-click in the Viewer to access the **Quick View** menu.

3. Click to select **Fit Image to Window**.

4. You can also select the **Arrange Layers** option to move one image layer on top of the other

5. Click the slider bar in the Viewer Swipe dialog and move it to the left and right to see how well the top image overlaps the others. Feel free to explore these viewing options.

6. When you are finished, click **Cancel** in the Viewer Swipe dialog.

7. Once you are done examining the orthoimage, choose **File | Close** from the Viewer menu bar.

Save and Close the Block File:

1. Now that you have verified the accuracy of the Leica Photogrammetry Suite output, in the main LPS dialog, click the **File** menu, then select **Save**. Notice that all of the columns are green except the DTM column, indicating that all of the process steps have been executed with the exception of generating a new DEM. We won't be doing this.

2. To exit Leica Photogrammetry Suite, choose **File | Close** from the main Leica Photogrammetry Suite dialog.

DUE: In your lab session Week of April 14th

Questions 1-3, triangulation reports and a brief individual report discussing the process you used to ortho-rectify your aerial photography. Provide comments on your final orthophoto product and what you noticed when reviewing the triangulation report (i.e., needed more GCP's in the northwest corner of EF-I-7 due to …).

You now know how to generate a digital orthophoto. Be sure to close and exit all windows and log off your computer.